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ANGEL OF PROVIDENCE.

Instructing Mankind to study and improve the Useful Arts.

THE

CABINET OF ARTS,

OR

General Instructor

IN

ARTS, SCIENCE, TRADE, PRACTICAL MACHINERY,

THE

MEANS OF PRESERVING HUMAN LIFE,

AND

POLITICAL ECONOMY,

EMBRACING

A Variety of Important Subjects.

By HEWSON CLARKE, ESQ.
OF EMMANUEL COLLEGE, CAMBRIDGE;
AND
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EMBELLISHED WITH APPROPRIATE ENGRAVINGS.

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DIRECTIONS TO THE BINDER.

THE

CABINET OF ARTS.

CHAP. I.

NATURAL PHILOSOPHY.

OF NATURAL KNOWLEDGE.

WHEN we consider the immense variety of objects which present themselves to the eye, it must appear, at first sight, impossible to acquire even a general knowledge of their qualities and properties. The longest life, with the most vigorous mind, and the most persevering industry, would be wholly unequal to the task of examining even the individual objects of all kinds with which a single man is surrounded. Hence it arises that, by a natural law of the human mind, we are always attempting to arrange the objects of our inquiries into certain classes, according to certain common properties which they seem to possess. These are divided into other classes, with additional marks of distinction; and these are again subdivided into other sets, until we at last come down to the individual object. By this process the mind is assisted in its inquiries, and the communication of knowledge is rendered easy and useful. The study of all the objects of our senses may be divided into two branches, namely, *Natural History*, and *Natural Philosophy*. The first of these branches is occupied in arranging objects, and describing them in such a way that they may be easily and accurately distinguished from one another. It may be considered as a descriptive view of the material world, in a state of rest or inactivity, without taking into account the motions or actions of bodies upon one another. This is the first step in the progress of knowledge, and it constitutes *Natural History*. But the operations of nature are seldom at rest: change succeeds change; new combinations of objects are formed, and new productions make their appearance. The primary planets revolve round the sun as their centre; the secondary planets or moons perform similar revolutions round their primaries. The air of

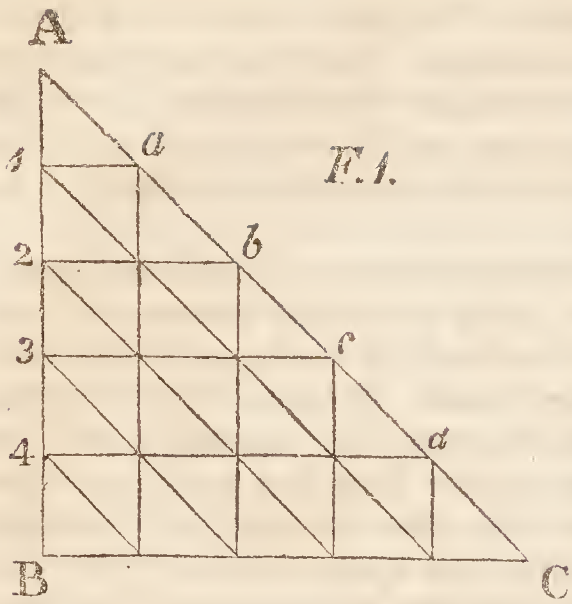
It has been reckoned that sixteen ounces of gold, which in the form of a cube or die, would not measure one inch and a quarter a side, would completely gild a quantity of silver wire, sufficient to go round the globe of the earth, or about twenty-five thousand English miles. *Mobility* is that property by which matter is capable of being taken from one part of space and transported to another. *Space* is an abstract term to express the place occupied by material bodies, which, in proportion to the greater or less space they fill, are said to be more or less extended. Matter possesses another property called *inertia,* that is inertness, or inactivity, by which it would always continue in the state in which it is placed, whether of motion or of rest, unless prevented by some external force. That matter at rest can begin to move of itself, no one will suppose: but it is not so evident that, when once set in motion, it would continue that motion for ever, if not prevented. It is natural to imagine that all material bodies have a tendency to pass from a state of motion to a state of rest, because we see all motions upon this earth gradually decay, and at last wholly cease. This, however, is occasioned by the interruption given to the motion by the resistance of the air, the friction of one body against another, &c. for if these are diminished the motion will continue the longer, and if they were entirely removed it would continue for ever.

Motion. Philosophers are induced at times to give explanations of terms already so simple and so well understood as to be incapable of any farther elucidation. This is the case with the term motion, which has been defined to be a change of place, or the act by which a body is made to occupy different parts of space, at different successive points of time. In bodies around us we are sensible of two kinds of motion, the one when an entire body is moved from one place to another, as when a stone falls from the hand to the ground, when a bird flies across the air, when a ship sails upon the ocean. Another kind of motion, not less real, although not so evident to our senses, is that of the parts of bodies among themselves. By this imperceptible motion plants and animals increase in stature, and the various changes of natural substances are produced. The gradual changes occurring in all bodies, in the course of time, show that the parts are continually acting upon one another; and perhaps in even the most solid bodies no particles are absolutely at rest, but all in perpetual action and motion. Motion can be communicated by one body to another: instances of this are perpetually passing before our eyes, and yet how this is done we are still totally ignorant; the fact is, however, so certain, that upon it the whole science of mechanics is founded. In considering motion several circumstances must be attended to. 1. The force producing the motion: 2. The quantity of matter in the moving body: 3. The velocity and direction of the motion: 4. The space moved over by the moving body: 5. The time employed in moving over this space: 6. The force with which it strikes another body opposed to it. The moving powers generally employed in giving motion to bodies are the action of men or other animals, wind, water, gravity or weight, the pressure of the air, and the elasticity of fluids and other bodies. The velocity of motion is measured by the space moved over in a certain time, or by the time employed in moving over a certain space. Hence the shorter the time and the greater the space moved over in it, the greater is the velocity: on the contrary, the longer the time and the smaller the space

moved over in it, the less is the velocity. If a body move over a thousand feet in ten minutes, we say its velocity is that of a hundred feet in a minute. If we would compare the velocity of two bodies A and B, of which A moves 64 yards in 8 minutes, and B moves 144 yards in 12 minutes, dividing each space by its time, we have the velocity of A to that of B as 8 to 12.

A body in motion must every instant tend to some particular point. If its tendency be always toward the same point, the motion will be rectilineal or in a straight line: but if the point of tendency be continually changing, the motion will be curvilineal. When a body is acted upon by one force or by more, all tending one way, its motion will be in the direction of the moving force or forces: thus if a man by a rope draw a boat to him, the boat will move in the direction of the rope. But if two powers, tending different ways, act upon a body, it will not move in the direction of either, but in one between the two. The consideration of this composition or resolution of motion is of the utmost importance in mechanics. If, for instance, a ship, in a current of the sea setting due east, at the rate of three miles in an hour, be acted upon by the wind blowing due north, at an equal rate of three miles in the hour, it is evident that the ship will sail neither north nor east, but in a direction compounded of these two; and as the two moving forces are of equal power, the ship's course must be equally distant between north and east, that is to say, in the direction of north-east. The space moved over by the ship in one hour, will in this particular case, be the diagonal of a square of 3 miles a side, or 4.24 miles.

Motion is said to be accelerated when its velocity is continually increasing, and uniformly accelerated when the velocity is equally increased in equal times. Motion is said to be retarded when the velocity is continually diminishing, and uniformly retarded when the velocity is equally diminished in equal times. The regularly increasing velocity with which a body falls to the ground, is an example of accelerated motion, being caused by the constant action of the principle of gravity, by which all bodies on the earth have a tendency to move towards its centre. By various accurate experiments it has been found that a body falling freely will descend 16 feet 1 inch (or in round numbers 16 feet) in one second of time. At the end of this time the body will have acquired a velocity twice that of the 1st second, which added to the velocity of the 1st, will give a velocity three times as great as that in the first period. At the end of the 3d period the body will have gained a velocity four times the original, which in addition to that of the preceding second, will produce a velocity equal to five times that acquired in the first period. By this progress, the velocities in each successive second of time will increase in the proportion of the numbers 1, 3, 5, 7, 9, 11, 13, 15, &c.; so that the velocity at the end of the 3d instant will be 5 times that of the 1st; at the end of the 5th instant 9 times, at the end of the 8th instant 15 times, &c. Hence if a body fall through a space of 16 feet in the 1st second of its motion, at the end of the 2d, it will fall through 3 times 16 or 48 feet more, that is 64 feet from the point where it began to fall; at the end of the 3d, it will have fallen through 5 times 16 or 80 and with 64 in all 144 feet from the point where the fall began; and so on progressively. Of the nature of accelerated motion some notion may be formed from the



annexed diagram. Let ABC, Fig. 1. be a right-angled triangle: divide AB and BC into the same number of equal parts, as here 5 for instance, through each of those divisions draw horizontal, perpendicular, and diagonal lines, as in the figure which is thus divided into 25 small triangles, all similar to ABC, and similar and equal to one another. Suppose a body to fall, by the constantly-increasing action of gravity, from A towards B, in 5 successive small but equal portions of time; then the horizontal lines 1*a*, 2*b*, 3*c*, &c. will represent the velocity of the body, at the end of the 1st, 2d, 3d, &c. portions of time, in which it continues to fall. In the 1st instant falling from A to 1, the velocity will be represented by the base 1*a* of the triangle A1*a*, which will represent the space passed over by the falling body in the 1st instant. In the next instant the body will fall to 2, its velocity will be shewn by 2*b*, which is double 1*a*, and the space passed over by the body will be represented by the figure 1*a*, *b*2. Now this figure contains 3 triangles, similar and equal to the first triangle A1*a*: the body at the end of the 2d instant has therefore acquired a new velocity double the original, which added to it, produces a treble velocity. In the 3d instant the body falls to 3; the velocity will then be 3*c*, and the space passed over in that instant is represented by the figure 2*b c*3. But this space contains 5 triangles equal A1*a*; being greater than the space of the 2d instant by twice the 1st space A1*a*; consequently if to the space passed over by a falling body, in any given period of time, be added twice the space passed over in the 1st equal period, the space to be gone through in the next succeeding period will be obtained. The spaces passed through by falling bodies will therefore increase in the proportion of the numbers 1, 3, 5, 7, 9, 11, 13, 15, &c. as was before stated.

The same diagram will give an idea of retarded motion, by proceeding in a contrary direction, ascending upwards from B to A. A body projected perpendicularly upwards from B, with a velocity represented by the line BC, will, by the counteraction of gravity, when it arrives at the end of the 1st instant at 4, have its velocity diminished to 4*d*: when it ascends to 2, it will have only a velocity equal to 2*b*, and on arriving at A, its projectile force being completely balanced and exhausted by gravity, the body will proceed no higher, will there stop, and, being acted on by gravity alone, it will begin to fall down with accelerated velocity to B, where it began to ascend. The reader will be aware, that experiments on the motion of falling bodies ought to be made above and not below the surface of the earth: because attraction being inherent in every particle of matter, a body sunk below the surface must be attracted upwards, by the particles above it, in diminution of the attraction of those below it, and its specific gravity is consequently lessened: so that were an aperture formed through the centre of the earth from surface to surface, and a pistol bullet dropped

into it, instead of passing through the globe, it would, from the velocity acquired in falling from the surface, pass a little beyond the centre, then return back for a still shorter space, and so after a few vibrations, like the pendulum of a clock, remain stationary in the heart of the earth. Experiments on falling bodies from the top of a lofty tower will be satisfactory: but those made in a deep well or pit must be inaccurate.

It was before shewn that a body acted upon by two uniform forces, in different directions, will move in a direction between the two, and in a straight line. If, however, one of the forces be regularly diminished, while the other continues unabated, the moving body will gradually draw nearer and nearer to the direction of the uniform force, and consequently describe a curve line. Thus, when a ball is thrown from a cannon (not perpendicularly upwards) it receives such an impulse from the powder as would carry it on in a straight line: but the resistance produced by the air gradually diminishes this original projecting force, so that it becomes less and less able to overcome the power of gravity, by which the ball is drawn down towards the centre of the earth. The consequence of this is, that the ball which proceeded from the mouth of the cannon in a course differing very little from a straight line, describes a curve bending more and more downwards, and at last falls to the ground. This curve was once supposed to be in certain cases a parabola, or that formed by cutting a cone by a plane parallel to one of the inclined sides: but experience has shown that, from the resistance of the air, and other causes, the curve described by a cannon-ball is very different from this section of the cone. On a knowledge of the curves described by projected bodies is founded the art of gunnery or artillery. The force with which a body moves, or which it would exert upon another body opposed to it, is always in proportion to its velocity multiplied by its weight, that is, by its quantity of matter. This force is called the *momentum* of the body, and upon the application of this property depends the whole art of constructing machines.

Attraction and Repulsion.—By attraction we mean the tendency of bodies, in certain circumstances, to draw near to each other, agreeably to the import of the term. Attraction is divided into various kinds; but as their causes are all equally unknown, it is uncertain whether they may not be all modifications of the same principle. These are the attraction of cohesion, of gravitation, of electricity, of magnetism, and chemical attraction. The attraction of cohesion takes place between bodies, only when they are at very small distances from each other; and by this it is that bodies preserve their form, and are prevented from falling in pieces. It would however appear that, in some cases, bodies when very near together, repel each other, so that although they appear to be in contact, they are not truly so, but will require considerable force to bring them to touch one another. If two pieces of lead be scraped very clean with a knife, and strongly squeezed together, they will adhere so firmly that they can scarcely be separated. The same effect will take place with plates of glass or marble wetted with water. The different degrees of cohesive attraction may be the cause of the different degrees of tenacity or hardness observable in bodies.

The attraction of gravity or gravitation, is that property by which all masses of matter tend towards each other, and which they exert at

all distances. It is by this property that a stone falls from a height to the ground: and it is by this that the heavenly bodies are retained in their several places, by their action on one another. It is a law of nature ascertained by the immortal Newton, that every particle of matter gravitates, or has a tendency to approach towards every other particle. This law is the grand leading principle of the Newtonian system of natural philosophy. The planets and comets all gravitate towards the sun, and towards each other, as does the sun towards them; each body in proportion to the quantity of matter it contains. All bodies on this earth gravitate towards a point at, or very near its centre, consequently they fall every where perpendicularly to its surface; hence the direction of a falling body on one side of the globe must be directly opposite to that of one falling at a point diametrically opposite to it. As this force of gravitation or of attraction is always in proportion to the quantity of matter in bodies, it is this which constitutes their respective weights. If two bodies containing equal quantities of matter were placed at any given distance asunder, in free open space, where nothing could interrupt their motion, they would be mutually and equally attracted, and at last meet in a point in the middle of their original distance. If, however, one of the bodies were greater than the other, as double its weight, the point of meeting would be as much nearer to the greater body as this exceeded the smaller body in weight. In all places equally distant from the centre of the earth the force of gravity is equal; but this earth not being a perfect sphere, as was explained when treating of Geography, its surface is not in all parts equally distant from its centre. The diameter at the equator is about 34 miles longer than that at the poles, consequently gravity is weaker under the equator than at the poles: hence it is, that the pendulum of a clock, (which is moved by its gravitation towards the centre,) adapted to the latitude of London, in $51\frac{1}{2}$ degrees, will require to be lengthened if carried towards the north pole, and to be shortened at the equator, in order to keep time as it did in London. All bodies possess some measure of gravity or weight, and, if at liberty, would equally tend to the centre of the earth: but smoke, vapour, &c. mount up in the air. This, however, is no proof that these substances have no real weight, but only that they are lighter than the air in which they float, which falls to the ground, and thereby forces the smoke, vapour, &c. to rise until they come to a region where the air is of the same gravity with themselves. When any substance is placed in one scale of a balance, so heavy as to make the other scale containing a weight to rise up, we do not suppose this weight and its scale to be absolutely light, but only that their gravity is overcome by that of the substance in the scale at the other end of the beam. The force of gravity regularly increases as bodies approach the surface of the earth: but below the surface this force regularly diminishes; so that it is greatest on the surface itself. In proportion as any body penetrates below the surface of the earth, more and more matter is collected above it, the attraction of which must act in a direction opposite to that towards the centre; so that a body at the centre of the earth being equally attracted in every direction all around, may be said to possess no real gravity. That great bodies of the earth possess attraction was clearly proved in 1774, from a set of experiments purposely instituted under the direction of the late Astronomer Royal, the Rev. Dr. Maskelyne,

and other members of the Royal Society of London. The experiments were made on *Shehallien*, a remarkable conical mountain, detached from all others, near Loch Tay, in Scotland, rising to an equal height with Snowdon, in Wales, viz. 3550 feet above the sea. A pendulum suspended by ingenious mechanism, on opposite points of the mountain, was found to be constantly drawn towards it, out of the true perpendicular line.

It was already said, that all motion produced by one power must be in a right line: when, therefore, we see bodies moving in curved lines, we may be sure that they are acted upon by more powers than one: for if all these forces cease to act save one, the body will again move in a right line in the direction of this single force. A stone in a sling whirled about by the hand acquires a force by which, if at liberty, it would be carried forward in a straight line to a considerable distance. Being retained, however, by the string, the stone is compelled to describe a circular motion until the string be let go, when it will proceed in a straight line, at right angles, to the direction of the string at the moment of its discharge, or in the tangent of the circle of its revolution. The stone in whirling round is acted upon by two powers, the one of the force impressed upon it by the whirling, by which it would fly off in the tangent, and so escape from the centre of the circle: hence this is called *centrifugal* force. On the other hand being held back by the string, the stone continues to revolve at equal distances round the centre of motion: hence this is called *centripetal* force.

If we lift a bar of iron, a block of wood, or any other solid body, in such a way that all its parts, in any position, will exactly balance one another, the point by which it is supported is called *the centre of gravity*. Suppose a solid block of timber, stone, &c. of a regular form, be set upon end on a level floor, it will have no tendency to fall to either side, and a line from the centre of gravity perpendicular to the surface of the earth, will pass exactly through the middle of the end on the floor. Let now the block be inclined to one side, the perpendicular from its centre will gradually approach that side to which the block leans, until it just coincide with the angle of the end and the lower side. At this point the block will have no inclination, either to return to its former erect position, or to fall over on its side: but if by leaning it still more, the perpendicular from its centre fall on the outside of the end next the floor, then the greater part of the weight being on the outside of the base, the equal balance will be destroyed, and the block will fall over on its side. The common centre of gravity of two bodies is that about which they would just balance each other. Thus, if two balls of lead, A and B, be fixed to the ends of an iron rod, and that A weigh 2 pounds, while B weighs 4 pounds, the point in the rod between them, on which the balls will balance each other, will be exactly as much nearer to the greater ball than to the less, as this last is lighter than the first. For, in order to make a balance or equilibrium between two bodies, the centre of gravity or point of support must be so situated that the distance of the one ball multiplied by its weight, shall be equal to the distance of the other ball multiplied by its weight. The weight of A is 2 pounds, and that of B is 4 pounds; the length of the rod connecting them is 12 inches: the distance of A from the centre of support, must therefore be double that of B, consequently if the rod be divided into 3 equal parts, 2 of them or 8 inches will be the distance

from A to the centre, and one of them or 4 inches, that between B and the centre, For 2 multiplied by 4 are just equal to 4 multiplied by 2. On this principle is formed the steel-yard, or balance, with arms of unequal length, as will be afterwards explained. When the perpendicular from the centre of gravity of our body falls within the base of our feet, we stand firm: if it fall without that base, we fall down on that side: and it is surprising to consider the various postures and methods to which a man has recourse, as it were instinctively, to retain or to recover his proper position. Thus, we bend our body forward when we rise from a chair, or in going up a stair, to assist our motion: and for the same reason a man leans forward when he carries a load on his back, and bends backward when he carries it before him, and to the right or left side, according as he carries it on the left or the right. In all these cases, the object is to place the body and the load in such a position that the perpendicular from the centre of gravity of both, may fall within the base of the feet. Hence appears the great error of persons rising hastily up, in a carriage or a boat, when likely to be overturned; for by so doing, the centre of gravity is thrown still farther from the base, and the machine must inevitably be overset. Whereas, had they instantly fallen down in the bottom, the centre of gravity would have been thrown more within the base, and the accident, probably prevented.

In regular bodies of an uniform substance, as in dry timber, stone, metals, &c. the centre of gravity will in general coincide with the centre of the figure, that is in the middle of the length, breadth and thickness. But in bodies of irregular shape the centre of gravity is found in this way. Suspend such a body by any point, with one side perpendicular to the horizon, and from the same point hang a plumb line; on the body draw a line where the string passes: do the same at any other point of suspension, and where these two lines meet, will point out the centre of gravity: for this being in each line it must be at the point where they meet.

MECHANICAL POWERS.

The mechanical powers are engines for enabling us to move and raise heavy bodies, and to overcome resistances, which, without their aid, we could neither raise nor move. In all machines three things are to be considered, the weight to be raised or moved, the power by which it is moved, and the instrument or engine by which the motion is effected. The mechanic powers are commonly counted to be six in number, viz. the *Lever*, the *Pulley*, the *Axis and Wheel*, the *Inclined Plane*, the *Wedge*, and the *Screw*: But these may all be reduced to two; for the pulley and the wheel are only assemblages of levers, and the wedge and screw are inclined planes. *The Lever* is the simplest of all machines, only a straight bar of wood, iron, or other substance, called a crow or a handspike, supported on a prop called a *fulcrum*. Levers are distinguished into three sorts, according to the different positions of the prop or fulcrum, and the power employed to move the lever: 1. When the prop is placed between the power and the weight; 2. When the prop is at one end of the lever, the power at the other, and the weight between them; and 3. When the prop is at one end, the weight at the other, and the power between them. Of the first sort of lever is the

common iron crow, for moving a block of stone or so, which rests on the one end, and the man applies his strength as a power at the other, while a small stone near the lower end serves as a fulcrum or prop on which the lever turns in its motion. Suppose a man press on the upper end of the crow with a power equal to 50 pounds, and at a distance of 48 inches from the prop, it is evident that he will be able to balance a weight of 400 pounds, placed within 6 inches of the prop, at the other end of the crow, (for 50 times 48 are equal to 6 times 400), and that by a little increase of his power, he will be able to raise that weight. Of the same sort is the poker in stirring the fire; the hand is the power, the coal in the grate is the weight to be moved, and the bar on which the poker rests is the fulcrum or prop. Of this kind of lever is also the common balance, although it be supported by suspension from above, and not upon a prop fixed below; but as the prop is placed in the middle of the lever, it is of no service in raising weights, because the power must be greater than the weight before the latter be moved. From this property of the first sort of lever is derived the Roman *statera*, or steel-yard, before mentioned. The point of suspension is placed very near one end of the beam; but that is made so massy as exactly to equal the weight of the long slender arm. At the end of the short arm is hung the scale containing the goods to be weighed, and the long arm is divided into a number of parts, each equal to the shorter arm. If any weight as 1 pound be placed at the 1st division, it will just balance 1 pound in the scale at the short end: but if it be placed at the 2d division, it will balance or weigh 2 pounds in the scale; if at the 3d division, 3 pounds, at the 4th division 4 pounds, &c. The 2d sort of lever has the prop at one end of the lever, and the power at the other, and the weight to be raised between them. The advantage gained by this sort, as in the former, is as great as the distance between the power and the prop exceeds that between the weight and the prop. When a man employs a crow or handspike, to move a block of stone in a forward direction, the point of the crow rests on the ground, under the block, which presses upon the crow a little above the end, and a moderate power raising up the other end of the crow, forces the block to move forward. Two men carrying a load upon a pole resting upon their shoulders, have the weight divided equally between them: but if the load be placed nearer to the one than the other, the nearest man will have a greater share to bear, in proportion as the distance between the load and the other man is increased; and if the nearest man come directly under the load, the whole weight will fall upon him. Suppose two men carry a load of 180 pounds on the middle of a pole resting on their shoulders, 6 feet asunder: in this case each will carry one half or 90 pounds: but let the load be placed within 2 feet of the hindmost man, and 4 feet from the foremost, the distances being as 1 to 2, the hindmost man will have to carry 120 pounds while the foremost carries only 60. By attention to this circumstance two porters of very unequal strength, may be made to bear just that share of a common burthen which is suited to the respective powers of each; daily experience, however, shows how little it is attended to, or rather how little it is understood. In the same way two horses, oxen, &c. of unequal strength, might be yoked so as to draw in proportion to their power, by placing the weaker animal as much farther from the drawing point of the beam as his strength is inferior to

that of the stronger. The oar of a boat is a lever of the 2d order: the blade rests in the water as a prop, the power of the rower is applied at the other end, and the weight to be moved, that is the boat, is between the two. Every door of a house or room is a lever of the 2d sort: the hinges are the props or centres of motion, the weight is the whole body of the door, and the power is the hand applied to the outer edge of the door, by which it may be easily moved. But if, by fixing a gimblet or a nail in the door, near to the hinges, we try to open and shut it, the force required will be very considerable, because so near the centre of motion. Cutting knives fastened at one end, used by coopers and others, and chaff-cutters, are levers of the 2d order. In levers of the 3d order, the weight is at one end and the prop at the other, and the power is applied between them. To this sort of lever are referred the bones of a man's arm; for when he lifts a weight by the hand, the muscle that exerts its power is fixed to the bone, about one tenth part of the distance of the hand below the elbow, which is the prop or centre of motion; the muscle must then exert a power ten times as great as the weight to be raised by the hand. This, however, has no relation to lifting a weight from the ground by the arm stretched down perpendicularly, by which a much greater weight may be raised. This kind of lever being the least advantageous of all, is therefore seldom employed: on some occasions, however, it is indispensable, as in raising a long ladder up against a high wall, when one end is kept fast on the ground, and the ladder is raised by strength of men's arms. When we draw a nail out of a piece of wood by means of a clawed hammer, we employ a lever of the 1st order. If the shaft of the hammer be 5 times as long as the iron claws, which draw the nail, the lower part of the head resting on the board as a prop, then by pulling the end of the shaft backwards, a man will draw the nail with one fifth part of the force that would be requisite to draw it out with a pair of pincers.

The good qualities of a balance depend much upon the following circumstances. The arms of the beam ought to be exactly equal, both as to weight and length: the points from which the scales hang should be in a right line passing through the centre of gravity of the beam; for by this the weights will act directly against one another,—if the fulcrum or point of suspension of the beam be placed in the centre of gravity, the beam will have no tendency to take one position more than another, but will remain steady in any, in which it may be placed; if the centre of gravity of the beam be immediately above the fulcrum, it will overset by the smallest action, the lowest end descending, and the upper part of the beam, if at liberty to turn over, becoming the lower:—but if the centre of gravity of the beam be immediately below the point of suspension, the beam will never rest in any position but when perfectly level or horizontal; and if put out of that position, and then left at liberty, the beam will vibrate up and down until it come at last to the level. From these particulars it follows, that, in a good balance, the point of suspension or support should be placed a little above the centre of gravity of the beam; its vibrations or balancings up and down will be quicker, and its tendency to the level position will be stronger, the lower the centre of gravity, and the less the weight upon the point of support. The friction of the beam upon the axis ought to be reduced as much as possible; the axis should be formed with an edge like a knife and extremely hard.

The *wheel* and *axle* are employed in a great variety of ways; the power being applied to the wheel, and the weight to the axle. Suppose a wheel of 6 feet diameter, and consequently of 18 feet 10 inches circumference, be fixed on an axle of 1 foot diameter, or 3 feet 1$\frac{5}{7}$ inch circumference. Let a rope be placed round the rim of the wheel by which the moving power is to be applied, and another round the axle, but in a contrary direction, by which the weight is to be raised. If the rope round the wheel be pulled until it go just once round, just as much rope will be drawn off as is equal to the circumference of the wheel. But while the wheel turns once round the axle does the same, and consequently the rope by which the weight is suspended will wind once round the axle, and the weight will be raised through a space equal to the circumference of the axle. The velocity of the power will therefore be to that of the weight in the proportion of the circumference of the wheel, to that of the axle; or the power will be to the weight raised as the diameter of the axle is to that of the wheel. But the diameter of the axle being 1 foot, and that of the wheel 6 feet, it follows that a power of 1 pound applied to the circumference of the wheel will balance a weight of 6 pounds suspended from the axle, and consequently that 6 pounds will be raised by a little more than 1 pound at the wheel. In this, and similar machines, the wheel and axle act as perpetual levers, of which the support is the centre of the axle of both, and the arms are the diameters of both. Hence it is evident, that the greater the diameter of the wheel in proportion to that of the axle, the greater will be the power of the machine; but the weight will rise proportionally slower. The capstan and the windlass of a ship act in the same way as the wheel and axle, in raising the anchor, or other weight; the bars or handspikes being like the spokes of a wheel without a rim. An axle moved by a crooked handle or winch acts precisely on the same principle.

If teeth be cut in the circumference of two wheels of the same size, A and B, and in the same number, if these wheels are made to work in one another, it is evident that they will both turn round in the same time, although in opposite directions; and a weight attached to the axle of the second wheel B, will be raised in the same time as if it had been attached to the first wheel A. But if the teeth of B be made to work not in the teeth of the circumference of A, but in others cut in its axle, then A must go round as much faster than B, as the number of teeth in B exceeds that of the teeth in the axle of A. If the teeth in the circumference of B be 72, and those in the axle of A be 12, it is evident that A must make 6 revolutions in the time of one revolution of B. In the same manner, three, four, or more wheels may be made to work in one another, and by duly proportioning the several wheels and axles to each other, any requisite degree of power may be produced. To this sort of engines belong *cranes* for raising great weights: but in these the wheel often has cogs instead of teeth, and a small trundle is made to work in the cogs, and turned by a winch. In all machines of this sort, it is necessary to apply a ratchet wheel, on the end of the axle, to which the weight is attached, with a catch to fall into its teeth. This will at any time support the weight, and keep it from descending, if the person who turns the handle should, through accident or carelessness, quit his hold of the winch, while the weight is raising. By this means the

danger would be prevented which has but too often happened, by the running down of the weight when unsupported.

The *Pulley* is a small wheel turning on an axis, with a drawing rope passing over the wheel: the wheel is usually called the *sheave*, and it is so fixed in the case or *block* as to turn on a pin, passing through its centre. Pullies are of two sorts, fixed and moveable. When a pulley is fixed to some elevated place, two equal weights attached to the ends of a rope passing over it, will balance each other; and if one of them be pulled down a certain distance, the other will rise an equal distance. This kind of pulley, therefore, gives no mechanical advantage; so that a man can raise no greater weight by it than he could by his natural strength. It is nevertheless of great use by changing the direction of the power and applying it with convenience. By it a man can raise a weight from the ground to any height, without stirring from his place, instead of carrying it up a long stair; by it he can employ not only his strength, but his bodily weight, in raising a load from the hold of a ship or a cellar: by it also, a number of men may be employed in raising a heavy body, which only two or three could conveniently handle without it; for any number of hands may be applied to the rope. The moveable pulley is fixed to the weight, and rises or falls with it. One end of the rope passing round this pulley is made fast to the frame above, by which the whole is supported, and the other is carried over another pulley made fast to the same frame above: the weight is suspended by a hook immediately under the centre of the moveable pulley. This pulley acts as a lever of the 2d order; the side of the wheel next to the fast end of the rope, is the fulcrum or prop, the power is the moveable rope at the other side of the wheel, and the weight is applied midway between the two. Consequently, any given weight at the centre may be raised by one half of that weight at the moveable rope, a man may therefore, by this moveable pulley, which rises with the weight, raise double the weight that he could raise by the fixed pulley. Or the effect of the moveable pulley may be considered in this way: the pulley is supported by two parts of a rope, the one fixed, the other moveable, which are equally stretched; each part must therefore bear one half of the weight; consequently a power equal to one half of the weight, exerted on the moveable part of the rope will be sufficient to balance the weight. In this way a number of pullies may be combined, by which very considerable weights may be raised by comparatively small powers. From the nature of blocks and ropes, however, and from the great friction occasioned by heavy loads, the power of a combination of pullies is much more limited in practice than might be expected. Considerable improvements were lately made on blocks, by employing, instead of a number moving separately, two of solid brass cut into grooves of different diameters: by this contrivance, the power was increased to the proportion of ten to one. If instead of one continued rope going round all the pullies, the rope belonging to each pulley be made fast at top, a different proportion between the power and the weight will be produced. In this case, each succeeding pulley will double the power of the one before it; if two pullies be employed, the power will sustain four times the weight, if three pullies, eight times the weight, if four pullies, sixteen times the weight, and so on. A pair of blocks with the rope fastened round them is termed a *tackle*.

The *inclined plane* is of great use in rolling heavy bodies, as casks,

wheel-barrows, &c. up to a height to which it would be very difficult to lift them directly. The force with which any body descends upon a slope, or inclined plane is to the force with which it would fall perpendicularly to the same level, as the height of the slope is to its length. Let the length of the slope be twelve feet, and the difference of level between its upper and lower ends be four feet, the force by which a body would roll down the slope, will be to that by which it would fall that height, is as four to twelve. Consequently reversing the case, a power equal to four, would be sufficient to support the body on the slope, while it would take a power three times as great, or equal to twelve, to support the body in the open air. Hence a cask, a cylinder, or any other rolling body may be moved up such an inclined plane, by a power a little more than one third part of that which would be necessary to lift the body directly to the same height.

From hence it is evident, that the longer the slope, in proportion to its height, the less power will be necessary to roll any body up it: and to this inclined plane may be reduced hatchets, chisels, and other edged tools, sloped only on one side.

The *Wedge* may be considered as formed of two planes equally inclined and joined together, and is used for cleaving and separating wood, stone, &c. This effect it would be impossible to produce by the lever, the wheel and axle, or the pulley: for the force of the blow applied to the back of the wedge, not only separates the parts which it touches, but shakes the adjoining parts, and renders them more disposed to separate when another blow is given to the wedge. It was before said that the momentum of any body in motion, is always equal to its weight, or quantity of matter multiplied by its velocity. The force given to a wedge is generally applied by a smart stroke, and not by dead pressure: for a sharp blow with even a small hammer will overcome more resistance than the constant pressure of a heavy weight; and a blow from a blacksmith's sledge-hammer will, in cleaving wood and stone, overcome a resistance of several tuns weight: nor have we any way of comparing the force of a blow with that of mere pressure or dead weight. In certain parts wedges of dry wood are used to separate blocks and layers of stone, by driving a number into the line where the separation is intended, and then moistening their outward ends with water, which penetrates into the wood, swells it, and thus by a gradual action, without violence, raises the bed of stone above the wedges from the lower mass. Axes, and such chisels as are sloped off to an edge from each side, act on the principle of the wedge.

The *Screw* can scarcely be considered as a simple mechanical power: for it is never used without the assistance of some of the others, as a lever handle or winch to turn it. The nature of the screw may be understood in this way. Out of a piece of strong paper cut a right-angled triangle, having the perpendicular much longer than the base. Fasten this base to a cylinder, and wind the paper round it, making the perpendicular side always to fall in the same place, by which means the inclined side will, at every turn of the cylinder, draw nearer and nearer to the perpendicular side; and at last coincide with it, at the angular point of the paper. In this way the inclined side of the paper will represent the winding or spiral groove or thread of the screw.—When this spiral thread is formed on the outside of a cylinder, it becomes a male screw; and when the groove is formed in the inside of a

cylindrical pipe, it becomes a female screw. The screw acts both as an inclined plane and as a wedge. The screw, in turning once round will enter the body it acts upon, or will raise it as much as the distance between any two threads. The closer the threads therefore are, the less force will be requisite to turn it; but the more time will be requisite to raise the body to any given height: the maxims holding good in this as in every other engine, that *what is gained in power is lost in time, and what is gained in time is lost in power.* A great degree of friction is always acting against the power in a screw; but this disadvantage is fully compensated in other ways: for on this account the screw may be stopt at any point of its operation; and it will retain the weight at any elevation, even when the power has ceased to act, or is taken away. Hence we see screws, properly applied, supporting a large building while the foundation is under repair: even large ships can be moved off the ground by means of screws.

Compound Machines. In practice upon a large scale, it is advisable to make use of the properties of different simple machines. In all compound machines simplicity is to be particularly attended to in their construction: for a complicated engine is not only the most expenssive, but it has always a greater degree of friction in proportion to the number of its parts, and is, therefore, much more liable to go out of order than one more simple. Whatever be the construction of a machine, its power will always be in the proportion of the velocity of the power to the weight to be acted upon; and provided that this be obtained in the highest possible degree, then the fewer the parts of the machine, the better will it answer its purpose. The power of a machine is not at all affected by the size of the wheels, &c. provided their proportions to each other be preserved. Formerly, the wheels of engines being generally of wood, they were made of a large size in order to be strong; but now that wheels of cast iron are employed, the size, is greatly reduced; by which, besides other advantages, much room is saved.

Fly Wheels. In all machines, the moving power acts with more or less irregularity, being at one time stronger, at another weaker. To correct this irregularity, and produce an uniform motion, nothing has hitherto been devised more useful than a *fly*, in the form of a heavy wheel, or of a cross-bar loaded with equal weights. This being set in motion, and made to revolve about its axis, maintains the power in its full force, and distributes it equally in all parts of its revolution. On account of the weight of the fly, small variations in the moving force, have no visible effect on its motion, whilst the friction and resistance of the parts of the machine prevent the fly from increasing the rapidity of its revolution. If the motion of the machine tend to become too rapid, the fly will slacken it, and if the machine tend to go too slow, the fly will quicken it. Every fly, or regulating wheel, should be fixed on that axis where the motion is swiftest, and should be made heavy when the motion is meant to be slow, and light where it is to be quick. In all cases the centre of motion, and centre of gravity of the wheel, should be the same point. The axis of the wheel may be placed either horizontally or perpendicularly. A small force is sufficient to set a heavy wheel in motion, which, if continued, will accumulate in such a manner as to produce effects in raising weights and overcoming resistance, which could not in any way be accomplished by the original moving force. This accumulation of motion in heavy wheels is of great ser-

vice in the construction of machines for various purposes, rendering them much more powerful and easy to be worked by men or other animals, as well as more even and steady, when set in motion by air, water, or other dead power. Hence the use of flies, ballast-wheels, &c. which are commonly supposed to increase the power of a machine, though in fact they, on the contrary, take something from it, and act upon a quite different principle. In all machines where a fly is used, considerably more power is necessary to set them in motion than when no fly is employed; or the fly may be set in motion itself, before the rest of the machine. This extra power is accumulated in the fly, which serves as a reservoir, from which the machine is supplied when its motion slackens. This is always the case in machinery worked by animals; for none are able to exert great force with perfect constancy. Some intervals of rest, although hardly perceptible, are necessary, otherwise the creature's strength would soon be exhausted. When the animal begins to work, he is fresh and vigorous, by which he not only moves the machine, but communicates power to the fly. When once in motion, the machine requires less power than at first; and the fly acting as an assistant moving power, the animal has a little interval to recover his strength. By degrees, however, the motion of the machine slackens, when the animal again is obliged to renew his exertions. The velocity of the machine would now be augmented, were it not that the fly acts as a resisting power, and the greatest part of the superfluous motion is lodged in it, so that the increased velocity is scarcely perceptible. Then the animal has another interval for rest; and thus, by this repetition of exertion and relaxation, the machine is kept in very uniform motion. The same thing happens in machines moved by water or by a weight. The strength of these, it is true, is not exhausted like that of an animal: but the yielding of its parts renders the impression of the power sensibly less after it begins to move. Hence the velocity is increased for some time, until the impulse becomes so feeble, that the machine requires an additional power to keep it in motion. Then it slackens its pace, the water or weight finds more resistance, and, of course, acts more forcibly, and the machine recovers its velocity.

Friction. If a horizontal plain surface were perfectly smooth, a body would be moved along it in any direction, by a very small force: but however even and smooth bodies may appear to the eye, yet their surfaces, if examined through magnifying glasses, will discover numberless inequalities. The point of the most delicate needle, when examined by a microscope, seems as rough as a bar of iron just come out of the forge. Hence it happens that when one body touches another, the heights and hollows of the one fall in with the hollows and heights of the other, by which they are, as it were, locked together. In moving the one along the surface of the other, unless they be a little separated, the roughness of each must be broken off, and the resistance this occasions is called *friction,* that is, rubbing; and if this be continued for some time, the bodies will lose their roughness, becoming smooth, or what we call *polished.* Friction increases in proportion to the weight or pressure, and the quickness of the rubbing. Wood slides more easily upon the ground in wet weather than in dry, and more easily than iron in dry weather, but not so freely as iron in wet weather. A cubic piece of smooth soft wood, weighing

eight pounds, moving on a smooth piece of soft wood, at the rate of three feet in a second, has a friction equal to better than two thirds of its weight. Soft wood upon hard wood has a friction equal to one sixth of its weight; and hard wood upon hard wood has a friction equal to one eight part of its weight. When wood rubs upon wood, oil grease or black-lead, properly applied, will diminish the friction to one third of what it would have been without it. Naves of wheels when greased have only one fourth of the friction they would have if they were wet. When polished steel moves on steel or pewter properly oiled, the friction is about one fourth of the weight; on copper or lead one fifth of the weight; on brass one sixth: and metals have more friction when moving on those of their own sort than when on those of a different kind. The friction between bodies that roll is much less than between those that drag. To perceive this, we have only to observe the difference between the locked wheel of a waggon going down hill, and an open wheel rolling in its ordinary way. Hence in some kinds of wheelwork, the axle is made to turn on several small wheels, or rollers, fixed in the inner circumference of the nave, and which turn round on their own axles as the great axle presses upon them. This contrivance, however, does not answer in very heavy machines, as the pressure is apt to wear the naves into notches; but in light and rapid motions they are extremely useful.

Animals employed as moving Powers.—A horse draws with the greatest advantage when the line of draught is not level with his breast, but inclines a little upwards. A horse drawing a weight over a single pulley can draw 200 pounds for eight hours a day, and walk at the rate of two miles and a half in the hour, consequently raise 1600 pounds: but if the same horse be made to draw 240 pounds, he will work but six hours a day, and not walk quite so fast; consequently raises or draws but 1440 pounds. When a horse draws in a mill or gin of any kind, great care should be taken that the walk or circle in which he moves, be as large as possible, otherwise much of his strength will be exerted to no purpose: if possible, it ought never to be less than forty feet in diameter. In a walk of nineteen feet diameter, it has been computed that two fifths of the horse's power is lost. The worst way of applying a horse is to make him draw or carry up hill: for if it be steep, three men will do more than one horse: each man loaded with 100 pounds, will move up faster than a horse loaded with 300 pounds. This is owing to the structure of the human body, which is better adapted for climbing than that of the horse. On the other hand, as a horse exerts his strength to the greatest advantage when drawing nearly in a level, a man possesses the least power in that way. Thus if a man, weighing 140 pounds, and walking along a river or canal, draw a boat or barge, by a rope coming over his shoulder, or otherwise fastened to his body, he will not draw more than twenty-seven pounds, which is only one twenty-seventh part of what a horse would draw in the same way. Five men are considered to be equal to one horse; and can, with the same ease, push round the horizontal beam of a horse-mill in a forty-foot walk: but three of the same men will push round a beam in a nineteen-foot walk, which is as much as a horse can do in that situation, although equal to five men where he can exert his strength to advantage. When a man carries a burden on his back, he exerts a great force very effectually, many muscles being employed in the ope-

ration. The muscles of his neck, back, and loins, keep his body and head in the proper position to sustain the weight: those of his shoulders and arms help to keep it in its place; and those of his thighs and legs raise the weight of the whole body and the burthen, as the man walks along. Working in this way, three men will do more than a horse, and two often do as much, as may be seen every day in the labour of a London porter. One of these men will carry a load of 200 pounds, and walk at the rate of three miles an hour: a coal-heaver will carry 250 pounds, but then he does not go far with his load.—Chairmen do not act with the same muscles as porters; but as they have straps brought down from their shoulders to the poles of the chair or loaded barrow, the muscles of the back, loins, and legs are all employed. Two chairmen will walk with 300 pounds (150 to each) at the rate of four miles an hour. The most effectual way for a man to exert his strength is in rowing a boat; for there he acts with more muscles than in any other way, besides being assisted by the weight of his body.

Mill-Work. In no manner has the knowledge of mechanic powers been rendered more subservient to the conveniences and comforts of human life than in the construction of *mills.* To enter into the particular formation of the various kinds of machines in which mill-work is employed, would, in a publication like the present, be impracticable. The following general observations, however, containing the substance of the conclusions, drawn by the most eminent engineers, from theory and experience, will be of use in giving a notion of the properties of the most important kind, namely, the corn-mill. Mills are distinguished into various sorts, according to the powers by which they are moved, and the purposes to which they are applied. Such are water-mills, wind-mills, horse-mills, corn-mills, fulling-mills, powder-mills, boring-mills, saw-mills, &c. In ancient times corn was ground by hand-mills, consisting of two stones, the upper concave, the under convex, like those of water-mills, but much smaller, the upper stone having a handle fixed in it, by which it was turned round. Such were the machines carried along with them by the Roman armies on their expeditions; and such are still to be seen in some of the remote islands of Scotland, where they are called *querns.* Water-mills are of three sorts, *breast, undershot,* and *overshot-mills,* so named from the mode in which the water is applied to the wheel. In the breast-mills the water falls down perpendicularly upon the float-boards or buckets placed round the circumference of the wheel. In the undershot mill, which is used where is no fall of water, the stream strikes the float-boards at the lower part of the wheel. In the overshot-mill the water flows over the top of the wheel, and is received in buckets placed all round it. The water-wheel stands perpendicularly, and is, in the best mills, from eighteen to twenty-four feet in diameter, including the float-boards, (See *Agriculture*) : the water striking on these boards, forces the wheel round, and gives motion to the mill. The axle or shaft of this wheel, which ought to be very strong, passes through the wall to the inside of the mill-house, where it is firmly supported. On it, within the house, is another perpendicular wheel eight or nine feet in diameter, having cogs all round that work in the upright staves or rounds of a trundle moving horizontally. This trundle is fixed upon a strong iron axle, called the

spindle, the upper end of which turns in a wooden bush fixed into the nether mill-stone, which lies upon beams in the floor above. By this contrivance, the running mill-stone is made to turn round in the same time with the trundle moved by the cog-wheel on the axle of the water-wheel. The upper stone is inclosed in a round box about an inch distant from its edge; and on the top of this box is supported the hopper, through which the corn is let down into a hole in the centre of the upper stone, whence it falls between the two. The rapid motion of the stone makes the corn draw more and more towards the outer edge, where it is bruised and ground, and then falls through a spout, called the mill-eye, into a trough placed to receive it. In order to cut and grind the corn, both the upper and under stones are furrowed or channelled obliquely and in contrary directions, from the centre outwards: so that the corn is forced to remain a considerable time between the stones, to be properly ground, before it can make its escape. The stones are also so cut that their faces are a little farther asunder at the centre than at the edges: by this means the corn, at its first entrance between the stones, is only bruised; but as it is whirled about and gets nearer to the outer edge, it is cut smaller and smaller, until at last it be ground as fine as may be required; for by a part of the machinery the stones can be placed at any distance asunder that may be necessary.

An overshot wheel having on it buckets instead of open float-boards, will turn with less water than a breast-wheel, where the fall seldom exceeds half the height of the wheel: so that where there is but a small quantity of water, and a fall great enough for the wheel to lie under it, the bucket, or overshot-wheel is always used; but where there is a large body of water with but little fall, the breast or under-shot wheel must be employed. Where the water runs upon a small declivity or slope, it can act but feebly on the under part of the wheel, which will then go round slowly; therefore the float-boards ought to be made long, in the direction of the axle, though not high, that a larger surface may be acted upon by the stream, and thus, what is wanting in velocity may be made up in power. In this case, when the water-wheel goes but slowly, the cog-wheel should have a greater number of cogs, in proportion to the rounds of the trundle, in order to give the mill-stone a sufficent velocity of motion. It was the opinion of the celebrated engineer *Smeaton*, that the powers necessary for producing equal effects on an undershot, breast, or overshot-wheel, should be to one another in the proportion of the numbers 48, 35, and 20. In the construction of water-mills, the following practical rules have been found to be the most advantageous.

1. Measure the perpendicular height of the fall of water in feet, above that part of the wheel on which the water begins to act: this is called the height of the fall. 2. Multiply this height in feet by the constant number 64.2882, and extract the square root of the product, which will be the velocity of the water at the bottom of the fall, or the number of feet that the water moves at that point in one second. 3. Divide this velocity by three, and the quotient will give the velocity of the float-boards of the wheel, or the number of feet they will go through in a second, when the water acts upon them in such a way as to have the greatest power in turning the mill. 4. Divide the circumference of the wheel in feet, by the velocity of the floats in feet in

a second, and the quotient will be the number of seconds in which the wheel will go once round. 5. By this last number of seconds divide sixty, the seconds in a minute, and the quotient will be the number of turns of the wheel in a minute. 6. The number of turns or revolutions of a mill-stone, four feet and a half in diameter, in a minute, ought to be 120, or two every second: divide 120 by the number of turns of the water-wheel in a minute, and the quotient will show the number of turns which the mill-stone ought to make, for one turn of the wheel. 7. Then as the number of turns of the wheel in a minute, is to the number of turns of the mill-stone in a minute, so must the number of staves or rounds in the trundle be to the number of cogs in the cog-wheel, taking them in the nearest whole numbers.

If the cogs of a wheel and the rounds of a trundle were put in as exactly as the teeth are cut in the metal wheels and pinions of a clock, then the trundle might be made to divide the wheel exactly; that is to say, the trundle might make any precise number of turns for one of the wheels. Such accuracy, however, is not required in mill work; and as the cogs and rounds cannot be set in so truly as to make all the intervals between them absolutely equal, skilful mill-wrights will always give the wheel what is called a *hunting-cog*, that is one more than will answer to an exact division of the wheel by the trundle.—Hence, as every cog comes to the trundle, it takes up the round next behind that which it took at the former turn. By this contrivance, all the parts of the cogs and rounds working upon one another will be equally worn, and to equal distances from one another, in a little time.

Clock-Work is so named from its being chiefly used in constructing clocks and watches, to point out the progress and divisions of time.—The origin of clocks with wheels is, by some writers, traced back to *Archimedes*, the celebrated geometrician, who fell at the taking of Syracuse, 214 years before the Christian era: by others, the invention is brought down much nearer to our own times. Be this as it may, it is certain that the art of making clocks, such as are now in use, was either invented, or at least recovered, in Germany above two centuries ago, for watches were first brought from that country to England in 1597, during the reign of Elizabeth. The discovery of pendulum-clocks is due to the ingenuity of the seventeenth century; the honour of making it being contested between the great natural philosopher Huygins, of Holland, and Galileo, of Italy. The former declares the pendulum was first used in 1657, while one is said to have been employed by the son of Galileo in 1649. Be, however, the inventor who he may, it is certain that the invention never flourished until it came into Huygins's hands. The first pendulum-clock made in England was the production of Fromantil, a Dutchman, in 1662, soon after the restoration of Charles II. At different periods, and in different countries, various instruments and contrivances have been employed for the measurement of time. The *clepsydra* of the ancient Greeks and Romans was a vessel of a certain size, filled with water, which ran out through a small hole in the bottom, in a given time. In some parts of India, the day is divided into certain portions by means of a hollow copper ball, having in it a small hole. The ball is placed on the surface of a vessel of water where it is slowly filled, and when full, sinks to the bottom. Our common sand-glass requires no description: the sand is, however, sub-

ject to irregularities in its running, according to the state of the weather, as is water according to the density of the air: for this reason, particularly in the half-minute glass used at sea, for measuring the rate of the ship's sailing, other substances have been recommended. Cut steel is sometimes employed; but the substance which seems to answer best is egg-shells well dried in the sun, and then beaten fine and sifted. In a common eight-day clock, the motion of the several wheels and pinions,, each divided into certain numbers of teeth, and acting upon one another, is produced by a heavy weight suspended by a cord wound round a cylinder or barrel. This barrel would of course be turned round by the weight with increased velocity, just as if the weight were falling freely from a height. The barrel is, however, fitted with a racket-wheel, attached to another wheel, connected with a succession of pinions and wheels composing the whole machine. The friction and weight of all these parts would retard the descent of the weight suspended from the barrel; but still its descent would be too rapid for use, and very irregular. To communicate, therefore, a regulated equable movement to all the parts of the machine, a part is annexed, called, from its hanging, the *pendulum,* by which the clock can be made to move fast or slow at pleasure. Suppose a leaden or other heavy ball to be suspended by a cord or metal rod from a fixed hook or nail: if the ball be raised to any height, and then let go, if it were at liberty, it would fall directly down to the ground; but the ball of the pendulum being retained by the rod or cord, cannot fall directly downwards, but must describe the arc of a circle, until it come perpendicularly under the point on which it is supended. Here, however, it cannot stop; for having in its descent acquired a certain velocity, it is made to describe another portion of the same circle, by ascending nearly as high on the opposite side of the perpendicular, as the point where it began to descend. Were there no resistance from the air, or friction at the centre of the motion, the pendulum would rise precisely to the same height, then fall back again, and ascend to the first point; thus rising and falling to equal heights in equal times, and continuing its swinging motion, or vibration, or oscillation, without end. This, however, is not the case: the vibrations grow gradually smaller and smaller, and at last the pendulum ceases to move: but if some other power be made to act upon the pendulum, sufficient to compensate for the resistance of the air and friction, it will continue its vibratory motion for any length of time that may be necessary. The pendulum being connected by a most ingenious contrivance to the machinery of the clock, two great objects are attained. Sufficient force is applied to the rod of the pendulum, to prevent its vibrations from diminishing, and by the regularity of its motions, those of the other parts of the clock are kept within the necessary bounds; so that the moving weight can run down only at a very slow rate. It was formerly noticed, in speaking of gravity or attraction, that this earth not being a perfect sphere, but swelled out at the equator, and flattened at the poles, gravity was more powerful at the latter than at the former parts, and that a pendulum calculated to vibrate seconds or any other portion of time at London in N. lat. fifty-one degrees and a half, would require to be lengthened if carried to the pole, and shortened if carried to the equator, in order to perform its vibrations in equal times. The length of a pendulum vibrating seconds, or sixty times in one minute, at London has been

found by accurate experiments, to be 39.13 inches, and not 39.2 inches, as commonly stated. The times of the vibrations of different pendulums are to one another in proportion to the square roots of their respective lengths; or the lengths will be to each other as the squares of times of vibration. Thus the pendulum of a common eight day clock beating seconds, or sixty times in a minute, is in length 39.13 inches; it is required to determine the length of the pendulum of a table clock which shall beat half seconds, or 120 times in a minute. Here say as the square of the number of vibrations in a minute 120, or 14,400 is to the square of 60, or 3,600, so is the length of the last pendulum 39.13 inches to a fourth quantity 9.78 inches, the required length for beating half seconds. So that a pendulum to beat twice as fast as another must be one fourth of its length, and one to beat only once for two beats of another, must be four times its length.

Table clocks and pocket watches are moved by the action of *springs* and not by weights. It is one of the facts observed in motion, that action and re-action are always equal and contrary. If you press upon the scale of a balance to keep it even with the opposite scale containing a weight of ten pounds, your hand is pressed upwards just as much as you press the scale downwards, and precisely in proportion to the weight in the scale; for if it require a certain measure of muscular power to balance a weight of ten pounds, one tenth of that power will be sufficient to balance a weight of one pound. If standing in a boat you, by a rope, draw towards you another boat with a man in it, the weight in both cases being equal, both boats will move forward until they meet at a point midway between their original positions. Upon this law of motion depends chiefly what is called the *elasticity* or *springiness* of bodies. An elastic body changes its figure by yielding to any impulse or pressure, but endeavours, by its own nature and force, to return to its original form. A piece of cane may be doubled and its two ends brought together; but as soon as it is at liberty it will suddenly return to its first straightness: the same thing happens in a thin slip of steel, and in some degree in various sorts of wood. All bodies hitherto known possess elasticity in a greater or less degree; but none perhaps are so perfectly elastic as to restore themselves with a force exactly equal to that with which they were compressed. The elasticity of certain bodies seems to depend much on their density, that is on the closeness of their component particles to one another; thus metals are rendered more dense and elastic by being hammered; cold condenses solid bodies, and renders them more elastic; but air, steam, and other similar fluids are rendered more elastic by heat which rarefies them, and enlarges the distance between their particles. An elastic body exerts its force equally in all directions round it; but the effect is chiefly perceived in that direction where the resistance is the weakest. In firing a gun, the elastic fluid produced by the inflammation of the powder acts on all sides equally; but the effect is visible only at the mouth of the barrel, where the resistance of the air is as nothing when compared with that of the sides of the piece. That the explosion acts backwards against the bottom of the barrel, with great force, no young sportsman will be inclined to doubt. The more any elastic body is compressed, the more power will it exert in returning to its original state; and this power which is at the greatest when the body is the most pressed together, regularly diminishes as the pressure is lessened,

and finally ceases when the pressure being entirely removed, the body resumes its first position. The spring of a table clock or a watch, is a thin long plate of fine hardened steel rolled up in a circular or rather spiral form; the inner end is fastened to an axle called the *spring-arbor,* and to the outer end is connected the cord or chain by which the motion is communicated to the works of the machine. When by turning round this axle by the key, the spring is bent and drawn into the smallest compass, it acts with the greatest force upon the chain, and compels it to turn the barrel or fusee on which it is wound; but as the spring unfolds itself its power is lessened; consequently the chain will act with lessening force on the barrel, and the motion of the machine will be gradually slackened. To compensate for this natural defect, the barrel on which the chain is wound, is not made cylindrical or of equal thickness throughout; but tapering to a point at one end. To the great end the chain is fastened, and thence wound round to the small end. By this ingenious contrivance, when the spring begins to act, the chain draws the fusee at the small end where it has the least power on it, and as the spring unfolds, and its power diminishes the chain comes to act upon the fusee where its thickness and diameter are increased. At last when the spring is opened nearly to its greatest extent, and is consequently weakest, the chain acts upon the fusee now enlarged to its greatest diameter, and consequently produces an effect equal to that produced in all the foregoing points of the motion. Pocket watches and many table clocks (often improperly called dials) contain only such machinery as is necessary for showing time by the revolution of the hands. Watches, which contain also the parts requisite for telling the hour by a bell are termed repeating watches. The most important improvements and application of watch or clock-work, are exhibited in the machines introduced on ship-board, for the purpose of pointing out the time, at some particular place, and thereby enabling the mariner to ascertain his position in longitude, east or west from the meridian of the place at which the time is pointed out by the machine. The *chronometer* or time-keeper, or marine-watch, was brought to the greatest perfection by Harrison of London, who, in 1764, received from parliament ten thousand pounds in reward of his long labour and ingenuity. One of his chronometers was carried round the world by Captain Cook in the years 1772—1775, and in all that time never erred but fourteen seconds in any one day, on which account another reward of equal value was granted to the artist. A watch of the same sort constructed by Arnold of London, during a trial of thirteen months, *on shore,* never varied more than six two-thirds seconds in any two days. Ingenious men in France were also employed on the same improvements in which they were eminently successful; it is not a little honourable, however, to British talent, that in a voyage of discovery to South America, performed by the Spanish government, twenty eight years ago, in which time pieces of the best construction from London and Paris were employed, it was discovered that much more confidence could be placed in the accuracy of the English than in that of the French chronometers. In watches the equal motion is produced by the vibrations of the balance wheel, in the same way as that of the clock is produced by the pendulum.

Wheel-Carriages. The most ancient carriages were probably the sledge, by which a weight is dragged along the ground, and the hand barrow carried between two men. Sledges are still employed among ourselves for particular purposes; a narrow sledge conveying small beer barrels may be seen in the streets of London; but in Amsterdam, Rotterdam, and other trading towns of Holland, heavy loads are drawn along upon sledges, which it is supposed have not the same effect as waggons, in shaking and deranging the artificial banks, forming the generality of the streets and quays of that country. In certain mountainous tracts of Scotland, Wales and Ireland, sledges are very useful, where wheel carriages could not be safely employed. In the northern climates of Europe, where the ground is covered with frozen snow for many months together, sledges are the common implements of transport for travellers as well as goods. The speed with which the Laplander skims along the frozen plains, in his light sledge drawn by the rein-deer, exceeds what we can easily believe; 150 or 200 miles, it is said, is no uncommon day's journey. Were the surface of the ground a plain of perfect smoothness the sledge would be the best machine of carriage; but on a rough surface the friction in swift motion is very great. Upon a perfectly smooth surface, a wheel, instead of revolving, would in general slide along like the sledge. This smoothness however does not exist; the roughnesses of the rim of the wheel fall in with those of the ground; the bottom part of the wheel is thus kept back, while the axle, nave and top of the wheel are drawn forward; thus a rotatory or rolling motion is produced. The advantage of wheels over the sledge will be manifest from this consideration, that the sledge suffers a friction in every part that touches the ground, which is not the case with the wheel. Suppose the circumference or rim of a wheel to measure eighteen feet, and that of the axle to be six inches. When the wheel goes once round, the carriage moves forward eighteen feet over the ground; but in all this space no friction takes place between the wheel and the ground, but only the application of different parts of the rim to the surface of the ground. The only sliding or friction takes place in the action of the end of the axle in the nave; hence the friction is reduced from eighteen feet to six inches, that is to one thirty-sixth part of that of a sledge, even when the axle moves to the greatest disadvantage. The touching parts of the axle and nave being thus reduced, they can be the more easily fitted to each other and kept smooth; the only inconvenience is the height of the wheels, which must always be added to that of the carriage itself. By the circulating motion of the wheels the friction is so much diminished, that a four wheeled carriage may be drawn with five times as much ease as a sledge sliding along the same surface. Large wheels have an advantage over small ones, because if the spokes be considered as levers, they act with a power proportioned to this length. All wheels, but particularly small ones, are apt to sink into the ground, and so to produce a constant obstacle to their progress. The fore wheels of four wheeled carriages are nevertheless made smaller than the hind wheels, that they may turn in less room; but the carriage would go much easier if all the four were of the same size. The small wheels must turn round as much faster than the large ones, as their circumference is less. When the carriage therefore is loaded equally heavy on both axles, the friction and

wear of the fore axles and wheels, must be much greater than those of the hind wheels. This ought to engage us to lay the greatest part of the load on the hind axle; but the general practice is just the reverse, by which course the friction is greatest where it ought to be least, and the fore wheels are pressed deeper into the ground than the hind, although they are with more difficulty drawn out of it than the latter. It is however true, that when the road leads up a steep hill, if the hind wheels be over-loaded, the fore wheels run the risk of being tilted up. It is not forgotten what an outcry was raised by the generality, not to say the whole of the carriers in this country, against the act of parliament requiring the use of broad wheels in waggons, and how hard it was to persuade them to conform to it, although they were allowed to employ more horses, and to draw greater loads than before. The main objection was, that as a broad wheel must necessarily touch the ground in many more points than a narrow wheel, the friction must of course be proportionally greater, and consequently the number of horses must be proportionally increased, to draw no more than the usual load. It did not occur to the objectors, however, that if the whole weight of the waggon and load bore upon the ground in a great number of points, each would have proportionally less weight to bear, than when the same was borne by only a few points of the wheels; and therefore, that the friction would be just equal, in equal degrees of weight. The truth of this assertion will be manifest by a very simple experiment. Fasten one end of a string to a brick, and the other to a scale of a common balance. Lay the brick on its edge on a table, and put as much weight in the scale hanging on the side of the table, as will, by its descent, draw the brick along the table. Then taking back the brick to its former position, lay it on its broad side, and you will find that the same weight in the scale will draw the brick along the table, just as it did when the brick was on its edge. In the first case the brick on edge may represent a narrow wheel, and in the last a broad wheel; and since the brick is drawn across the table with the same power and ease, whether lying on its broad or its narrow side, it shows that a broad and a narrow wheel may be moved along the ground with the same ease, supposing them equally heavy, even although they should be dragged and not roll in their course. It is also to be considered that, as narrow wheels are always sinking into the road, they in fact move as if they were going up hill even when on level ground; and their sides are liable to considerable friction against the sides of the ruts. But these inconveniencies are avoided by the use of broad wheels, which besides, instead of cutting up the road, roll it even smooth and hard, as constant experience fully proves. Upon the continent prejudices are still very powerful against the use of broad wheels. In France, for instance, where the formation and maintenance of the great roads are under the immediate administration of government, these roads are carried on as much as possible in straight lines, and of a very spacious, perhaps an unnecessary breadth, strings of heavy carriages with narrow wheels follow one another in the same or in parallel tracks, so that after a course of rain the road has, in some shape, the appearance of a furrowed field. To prevent this mischief, as gravel is scarce in that country, a broad space in the middle of certain much frequented roads

is paved or pitched with granite, like the streets of a town, leaving a sufficient earthen road on each side.

If wheels were always to run upon smooth level ground, the spokes ought to be set in perpendicularly to the naves and axles; because they would then bear in the strongest direction of the wood. Ground being in general more or less uneven, one wheel falls into a hollow or rut, when the other is on a height, in this position the wheel in the hollow bears a great deal more than the other. To obviate this disadvantage what are called *dishing* or concave wheels have been introduced. The hollow of the wheels looking outwards, it follows that when one is in a hollow, and the other upon a height, the spokes of the lower wheel, (which upon level ground are inclined inwards toward the carriage,) stand perpendicular, and therefore are in their strongest position at the time when, by the inclination of the ground, the greatest weight is thrown upon them. The advantages of dishing wheels are still very imperfectly known or turned to use, in most parts of the continent.

SECT. II.

HYDROSTATICS.

By *Hydrostatics,* in general, is meant the science which treats of the mechanical properties of water and other fluid substances; that is to say, of their nature, gravity or weight, pressure, and motion, and of the methods of weighing solid bodies, in them. The consideration of the properties of fluids, when in motion, is more particularly termed *Hydraulics,* from two Greek words allusive to a water-pipe. This last branch is of the utmost importance in life, as upon its principles are constructed all sorts of *pumps, fire-engines, conduit-pipes* for conveying water from one place to another, *canals,* on which depends so much of our inland commerce, and of the embellishment of rural scenery. Again, Hydrostatics treat of the weight and equilibrium or balance of fluids at rest, and hydraulics of the laws of fluids in motion, that is, when the equilibrium or balance is destroyed.

A fluid is a body, the parts of which readily yield to any pressure, and are easily moved among themselves. Fluids are of two kinds; elastic, such as the air of the atmosphere, and the different sorts of *gas,* which may be all compressed into smaller spaces than they at first occupy; non-elastic fluids are water, oil, mercury, &c. which are nearly incompressible. It is with the latter class, or rather with water alone, that we are now particularly concerned. The cause of fluidity is still unknown. Some philosophers have thought that the particles of fluids are globular, and of various sizes, by which properties they touch each other in only a few points, and therefore may be easily moved amongst themselves. Others are of the opinion that these particles possess but little mutual attraction, and consequently adhere but feebly to one another. It is owing to this weak cohesion that the surface of fluids will, when at liberty, always place itself in a direction at right angles to a line, tending to the centre of the earth, that is, in a level or horizontal, direction; for the particles being very feebly attracted by one another each will be independently acted upon by gravity, and consequently all

will be arranged at equal distances from the centre, as far as space is afforded for their motions. Every one knows that fluids have weight or gravitate, when considered by themselves; but it was long supposed that a quantity of a fluid had no weight, as long as it was covered and immersed in a larger body of the same fluid. As a proof of this, we were referred to the fact that a bucket of water is drawn up with great ease, while it is below the surface of the well, and the weight was suddenly increased as soon as it rose out of the water into the air. To explain this, we are to reflect that fluids possess the remarkable property of pressing, not only perpendicularly downwards, as solid bodies do, but also upwards, sideways, and in all directions equally. Hence it is by the upward action of the water in the well that the bucket so easily rises; for the water in the bucket being of the same weight with that round it in the well, it is evident that only a small force in an upward direction will make the bucket rise to the surface. At that point, the upward pressure of the water ceases, when, to draw up the bucket and water, will require a force more than sufficient to countervail the total gravity or weight of both. The upward pressure of fluids may be shown be the following simple experiment. Take a straight tube or pipe of clear glass, that the action of the fluid may be seen, and open at both ends. Close one end with with your finger, and plunge the other to any convenient depth in a vessel of water. In this case the water will rise but a little way in the pipe, because the air within it resists its ascent. Now take off your finger from the upper end of the tube, when the air will escape, and the water will rise in the tube precisely to the level of the water in the vessel on the outside. The same effect will be produced whether the tube be straight or crooked, whether it stand upright or inclined in any direction. Upon this property of fluids rising always, when at liberty, to the same level in all their parts, it is that water conveyed in a close pipe from a spring, may be allowed to descend to great depths, and will again ascend to the level of the source. That fluids press also laterally or sideways, is plain from the force with which they flow from a hole in the side of a full vessel. As fluids press equally in all directions, it follows that the pressure on the bottom of any vessel, whatever be its shape, is always in proportion, not to the quantity of fluid in the vessel, but to the area of the bottom multiplied by the depth of the fluid. Thus, in a cylindrical vessel of the same width throughout, the pressure on the bottom must be equal to that of the quantity of fluid: but if other vessels be made on equal bottoms, and of equal heights with the cylinder, the one spreading out like a tumbler or funnel, and the other contracting upwards like a tumbler or funnel turned down, the quantities of fluid in those two vessels must be very different from that in the cylinder; but the pressure on the bottom of all those will be equal. A property of fluids of great importance is this, that a quantity, however small, may be made to counterpoise a quantity, however large. In solid bodies a pound will only balance a pound, a hundred will only balance a hundred, &c.; but in fluids, a pint may be made to balance a gallon, a hogshead, &c. If to a wide vessel, containing a large quantity of water, a tube or pipe, however small, be connected at the bottom, and water be poured into them, it will rise and stand at the same level in both the pipes and the vessel. This happens whatever be the shape of the vessel and tube; and it shows the

two quantities of water, in this position, to be in equilibrium, or to balance one another. Hence we see that the pressure of fluids is very different from their gravity or weight. The weight is in proportion to the quantity; but the pressure is proportioned to the perpendicular height. The same thing may be shown by means of what is called the hydrostatic bellows. Take two oval or circular boards, eighteen inches broad, connected together by a broad band of leather, like common bellows, but having no air-hole or valve. To the lower part of the side-leather fix a small pipe, communicating with the inside, and three or four feet high. Pour a little water into the pipe, which will enter the bellows, and raise up the upper board. Then lay weights on the upper board, and pour in more water by the pipe, when the weight wll be forced upwards, to the utmost extent of the leather sides. By this means, if the pipe be kept full, even if the water should not weigh half a pound, it will force up the board loaded with 300 pounds. Hence, if a man stand on the bellows, and pour water, or even blow into the pipe, he will raise himself up, provided the bellows be air-tight.

Specific Gravities. It is common, in speaking of different substances to describe one class as heavy and another as light; but the fact is that all bodies must possess some portion of matter, and consequently of weight. Thus we say smoke and vapour are light because they rise in the air, and a stone is heavy because it falls to the ground. A piece of lead is called heavy because it sinks in water, while a piece of dry wood, a straw, a feather, are counted to be light because they do not sink in water. The fact is, however, that weight being always equal to the quantity of matter, if this matter be compressed into a small compass, the substance will be heavy in proportion to its bulk, while another in which the matter is spread out to a great bulk, will be comparatively far less heavy. By comparing the relative weights of different substances in proportion to their bulk, we learn what we call their specific gravity. In these comparisons, some fixed standard must be employed: this is usually fresh water distilled to purify it. A body of the same weight, with an equal bulk of this water, will remain suspended in it; but if this body be heavier than an equal bulk of water, it will sink to the bottom, and if it be lighter it will swim on the surface. A penny-piece sinks in water because it is nearly eight times heavier than an equal bulk of water; but a piece of dry fir deal will swim, because it is little more than half the weight of an equal bulk of water. (See the following Table of Weights.) A body suspended in water loses as much of its weight in air as is equal to a quantity of water of the same bulk: and if the weight of the body weighed out of the water be divided by the weight it loses when weighed in the water, the quotient will show how much the body is heavier than a quantity of water of the same bulk. Take a cubic piece of bar iron, weighing just five pounds avoirdupoise, or 1280 drachms: dip it in distilled water, and then weigh it again. The weight will now be reduced to 4 lb. 5 oz. 14 dr. or 1118 dr. showing a loss of weight of 10 oz. 2 dr. or 162 dr. Divide the weight in air, 1280 dr. by this loss 162 dr. and the quotient 7.88 will give the specific gravity of bar-iron when compared with pure water; that is, that the iron is nearly eight times as heavy as water. Again, a new

guinea of the regulated standard should, in the air, weigh 129 grains, but in water it is found to weigh only 121 grains and three-fourths. This shows that a quantity of that water, equal in bulk to the guinea, weighs only seven grains and a quarter. Dividing the 129 grains by this quantity, it will show standard coin gold to be 17.793, or nearly eighteen times heavier than water. If the quotient be eighteen or upwards, then the gold is very fine; but if it be seventeen or less, it has had too great a proportion of alloy or inferior metal mixed with it.

The weight of bodies in water, or any other fluid, is discovered by a balance very like the common one, but very nicely made, having, at the bottom of one of the scales a hook on which to hang the substances to be weighed, so as that they may sink into a vessel of water, without wetting the scales; for weighing bodies lighter than water, an additional contrivance to sink them is employed. For finding the specific or relative gravity of fluids, an instrument, called the *hydrometer*, or water measurer, isused, consisting of a hollow copper ball, to which is attached a flat brass wire, marked with a number of equal divisions. By means of some small shot or quicksilver, occupying the lower part of the ball, when placed in any fluid, it floats or sinks in such a way as to keep the wire always upright; and the lighter the fluid into which the hydrometer is dipped, the deeper will it sink, and so point out the degree upon the divisions of the wire.

By a number of accurate experiments on substances of various sorts, tables of their gravities, compared with that of distilled water, have been formed, from which the following brief statement is extracted. The weight of distilled water is the same all over the world; and the quantity of it contained in a cubic vessel of one foot in length, breadth, and depth, or in 1728 cubic inches, weighs 1000, or more precisely 998 ounces and three quarters avoirdupoise. In this list the substances are arranged in the order of their weight, from the heaviest to the lightest, stating that of distilled-water at 1.00.

Table of Specific Gravities.

Solids.		Solids.	
Platina hammered	20.38	Iron cast	7.21
——— pure and melted	19.50	Zinc	7.19
Gold pure and hammered	19.36	Antimony	6.70
——— cast	19.26	Arsenic	5.76
—— standard hammered	17.59	Oriental Ruby	4.28
——— common	17.49	Emerald of Peru	3.77
Mercury	13.57	Diamond	3.52
Lead melted	11.35	Flint Glass, English	3.29
Silver pure and hammered	10.51	Alabaster	2.73
——— cast	10.47	Marble, white	2.72
—— standard of coin	10.39	Slate, common	2.67
Copper in wire	8.88	Flint or Silex	2.66
Brass cast	8.40	Rock-crystal	2.65
Steel hardened	7.82	Glass, green	2.62
Copper melted	7.79	Agate	2.59
Iron in bar	7.79	Crown Glass, English	2.52
Tin melted	7.29	Limestone, from 1.39 to	2.39

Solids.		Solids.	
Magnesia	2.30	Fir, dry	.55
Lime	2.30	Cork	.24
Alum	2.00		
Sulphur	1.99	**Fluids.**	
Ivory, dry	1.82		
Ebony	1.12	Sulphuric Acid	1.85
Amber	1.08	Nitrous do.	1.58
Camphor	.99	Fluoric do.	1.50
Wax	.97	Marine do.	1.20
Tallow	.94	Sea-water	1.03
Oak, dry	.93	*Fresh-water distilled*	1.00
Pumice	.91	Linseed Oil	.94
Ash, dry	.80	Olive Oil	.91
Maple, dry	.75	Spirit of Wine, common	.84
Elm, dry	.60	———— pure	.82

N. B. In the preceding list of solid substances is reckoned mercury or quick-silver, although it be always found in nature in a fluid state; where uncombined with sulphur or other substances; because it possess all the other qualities forming a solid metallic body. By intense cold, natural as well as artificial, mercury can be made solid and malleable, or capable of being beaten out with a hammer.

Diving-bell, &c. On a knowledge of hydrostatics, or of the relative weights of common air, water, and other fluids, are constructed two machines, which have excited much attention, although the world has not yet reaped from either all the benefits they seem capable of producing. These are the *diving-bell,* and the *air-balloon.* The nature and principles of the diving-bell may be understood from a simple experiment. Take a common glass tumbler, and place it with the mouth over, and inclosing, but not touching a small piece of paper, floating on the surface of water in a bason. Pressing the tumbler down into the water, you will see that the paper, and consequently the water, rise but a very little way within the tumbler, the air within it opposing the rise of the water, although being elastic and compressible, it is forced into a space smaller than it had before, by the external upward pressure of the water. The first diving-bell of any importance was made a hundred years ago by the celebrated astronomer, Dr. Halley: it was in the shape of a bell, and coated with lead, so as to sink even when empty; weights were fixed to the lower edges, to keep the machine in an erect position; it was three feet wide at top, five feet wide at bottom, or the mouth, and eight feet high. In the top was a clear strong glass to let in the light, and also a cock, by turning which the heated air was allowed to escape. The machine was suspended from the mast and yards of a ship, in such a way as to be let down into the sea over its side. Round the inside near the mouth was a seat for the divers. To supply the bell with fresh air, two barrels of sixty-three gallons each were made and cased with lead to make them sink when filled only with common air. To a hole in the top of each barrel was fixed a leather pipe or hose, long enough to fall below the mouth of the bell, by which the air in the barrel was forced into the bell by the pres-

sure of the water, let in by a small hole into the barrel. By this method fresh cool air was admitted into the bell, and the foul heated air was let out by the cock in the top, so that Dr. Halley, with four other persons, was able to remain under water, at a depth of nine or ten fathoms, for an hour and a half at a time, without experiencing any bad consequences. By the glass above, they had light enough, when the sea was still, to read and write, and take up any thing that lay on the ground within the compass of the bell. Since Halley's time, many others have been constructed with various improvements, by which the bottom of the sea has been examined, and various articles of value that had been lost, have been recovered by attaching to them ropes communicating with a ship, by which they have been hoisted up and taken on board.

The *air-balloon* is a globular or spheroidal bag of silk, or other light but strong material, varnished over so as to be air-tight. Over the balloon is thrown a net, having the meshes smallest at the top, where the pressure of the internal vapour is the strongest. To the lower end of the net under the balloon is suspended the car or boat, of slender wicker work, to carry the aerial traveller. A cubic foot of common air weighs above 554 grains, and by heating it to a certain degree it will expand to double that bulk, when a cubical foot will weigh only half that quantity. If therefore the air within a balloon can be heated so much that it, with the materials of the balloon, &c. shall together be lighter than an equal bulk of the external air, then, as happens in solid bodies in a fluid, the balloon must ascend until it arrive at a region where the external air is just as light as the balloon itself, and there it will remain. To maintain the heat of the air within the balloon the first were constructed with a small grate, for burning straw and wool; but the great danger of setting fire to the machine soon led to the employment of what is called inflammable air, (hydrogen gas,) now always used. This air is obtained by putting the filings or turnings of iron with oil of vitriol, (now called sulphuric acid,) weakened with water, into casks lined with lead, from the tops of which tin pipes convey the inflammable air or vapour into the balloon.

Air-balloons were first constructed in France by two brothers named *Montgolfier* in 1782; but as early as 1766, some eminent British naturalists, Mr. Cavendish, Professor Black of Edinburgh, Mr. Cavallo, &c. had made various experiments of a similar nature. By Mr. Cavendish, the weight of inflammable air was ascertained to be but one seventh of that of an equal bulk of common air. The motion of a balloon in the air is very different from that of a ship on the sea; for the balloon being entirely enveloped in the air, can be acted upon by it alone, and must therefore follow all its motions, and no other; whereas the sails, and a great part of the body of the ship are exposed to the impression of the air, while the lower parts of the body are immersed in the water, through which it may be made to move in various directions, by the force of the winds. Hitherto no method has been devised of giving to a balloon a direction or velocity in any respect different from those of the current of air in which it floats; that such a discovery may in future be made, however, it would be rash to deny. When a balloon was first exhibited at Paris in 1782, the celebrated Dr. Franklin was asked what uses he thought might be made of such a machine. *It is a new-born infant,* said he, *no man can foretel what it may come to.*

The earliest experiment on the specific and relative gravities of different substances, of which we have any account, is that made above two thousand years ago by Archimedes, a man of singular acuteness in philosophical researches. Hiero, king of Syracuse in Sicily, having given to an artist a quantity of pure gold to form a royal crown, suspected, when the work was done, that some of the gold had been kept back, and a base metal mingled in its place. Applying to Archimedes to ascertain the fact, the geometrician was long embarrassed in the enquiry; at last one day as he stepped into a bath, it struck him that, in proportion as he went deeper into the water, it rose on the sides of the bath. Hence he was led to reflect, that a body of any other shape, but of equal bulk with himself, would just raise the water to the same point; but that one of equal weight consisting of heavier materials, and consequently of less bulk, would not raise it so high. Feeling the answer to the king's question to be now within his reach, Archimedes sprang out of the bath, and ran home, crying out as he passed along the Greek words *heureka, heureka,* I have found it out.—I have found it out. Preparing a mass of pure gold equal in weight to the crown, he weighed them both in water, and found the gold to weigh in it more than the crown; and likewise that the crown displaced more of the water than the mass of pure gold. Making similar comparisons of the weight and bulk of the crown with silver, copper, and other metals, he was at last enabled to determine the quantity of pure gold and of the baser substance combined in its composition.

HYDRAULICS.

BY hydraulics, an application of hydrostatics, we are taught to estimate the force and velocity of fluids in motion. On the principles of hydraulics entirely depend various machines and engines worked by water, such as mills, pumps, fountains, &c. also the construction of canals, locks, conduits, &c. If an open vessel be filled with water, and in it be made two holes of the same size, the one in the bottom, and the other in the side close to the bottom, equal quantities of water will be thrown out, in equal times from both holes. At first the force and swiftness of the water are the greatest, and they gradually diminish as the water in the vessel is lessened. From observations on the pressure of fluids, this rule is derived, that the velocity or swiftness, and consequently the quantity, of water spouting out through a hole in the bottom, or in the side of a vessel, are always in proportion to *the square root* of the depth or distance of the hole below the surface of the water. The pressure of fluids against the side of a vessel is as *the spuare* of the depth, of course to make *double* the quantity of water run out through one as runs out at another, it will require *four* times the pressure; therefore, the first hole must be placed *four* times lower below the surface of the water;—to make *thrice* the quantity flow out the hole must be made *nine* times lower, &c. This will appear from experiment. Fill a deep vessel with upright sides with water; in the side make two holes, the one nine inches and the other four times lower, that is thirty-six inches, below the surface of the water; in these holes fix two pipes of equal bores; and keep the vessel always full to the same height. The

velocity with which the water spouts out from different apertures being as the square root of the respective depths; and the root of 9 inches being 3, and that of 36 being 6, the double of 3; it will follow that the lower pipe will, in any given time, discharge double the quantity that flows from the upper pipe. If therefore, a pint measure be held to the upper pipe, and a quart to the lower, both vessels will be filled in the same time. The horizontal distance to which water will spout, before it touch the ground, from a pipe in the side of an upright vessel, is always greatest when the hole is made in the middle of the depth of the water, and it is always equal to the whole of that depth. From other holes above or below the middle, the water goes to a less distance; and this distance is always the same when the water flows from pipes placed at equal distances above and below the centre pipe. If again a number of pipes be fixed at the junction of the side and the bottom of the vessel all pointing upwards with different degrees of inclination, that inclined at an angle of forty-five degrees, that is at equal distances from the perpendicular, and the horizon, will throw the water to the greatest distance, which will be always equal to the depth of water in the vessel.

Pipes. It was before observed, that water or any other fluid may be conveyed in a pipe to a great depth, and will again ascend to the level of the source. Bend a leaden pipe nearly double; hold both ends upright, and pour water into one leg, when it will rise in the other leg to the same height. If the water in the one leg weigh two pounds it will just balance and support two pounds in the other leg; but as the weight in both is supported by the middle and lower parts of the pipe, the weight and pressure upon that part must be equal to both, or to four pounds. Hence we may perceive the necessity of greatly strengthening the lower parts of a water pipe, when placed much below the level of the two ends, as must happen when the water is conveyed from one hill to another across a deep valley. This becomes still more necessary, when it is considered that the pressure is besides in proportion to the square of the height of the water, that is to the perpendicular depth of the valley, below the beginning of the pipe. It is a common opinion that the ancients were ignorant that water, in a close pipe, would rise to the level of the source; and this prejudice was carried so far that commentators on *Vitruvius, Frontinus,* and other ancient writers who treat on this subject, charged them with using language devoid of meaning. That this opinion was entirely unfounded, however, has been shown in many cases, but particularly by the very important discovery, made in the middle of last century, of large and strong leaden pipes laid by the Romans, for a course of many miles, over great inequality of ground, to convey water to the city of Lyons in the south of France. That this was not, however, the general practice, is evident from the prodigious works constructed by the ancients, for conveying water along ranges of arches or aqueduct-bridges, of which the remains still astonish the eye. The country round *Rome* is particularly distinguished by these monuments of splendid utility; some of them, stretching for miles together to the hills, are still so entire, after a lapse of two thousand years, as to convey abundant streams of water to different quarters of the town. It is not merely on account of the pressure of the water that the pipes should be strengthened in hollows; a certain quantity air is always carried along with the water, which, accumulating in the lowest

parts, acts so powerfully as frequently to burst the pipe, when no other way is opened for its escape.

Syphon. This is a bent pipe usually employed to draw off liquors from a cask, &c. by making the fluid rise above the level of the surface in the vessel. Take a small pipe bent into two legs of exactly the same length; fill it with water, and turn the two ends downwards precisely to the same level; in this case the water will not run out, but remain suspended in both. If however the pipe be held to one side, so that one end of the pipe shall be a little lower than the level of the other, the water will immediately flow from the lower mouth, and empty the whole pipe. The cause of this is the following. Common air is a fluid of which the density and weight, on the surface of the earth, is found by experiment to be to that of water, at a medium about as 1 to 820, so that 1 gallon of water is as heavy as 820 gallons of air on the earth's surface. Now the air, like every other fluid pressing equally in all directions, when the two legs of the syphon are turned down to the same level, the weight of the atmosphere above being kept off by the middle of the machine, the air below bearing up the water in both ends, and of the same weight, it falls out of neither. If however one of the legs be brought to a lower level than the other, thus in fact lengthening the lower and shortening the upper leg, the balance is destroyed, and the water in the lowest or longest leg will of course preponderate and run out. For this reason, in practice the legs of the syphon are made of unequal lengths. To make a syphon act, as for instance in drawing the liquor out of a cask upon a cart, both legs are filled with the liquor, and the ends stopped with the finger; the short leg is then quickly introduced by the bung-hole into the liquor in the cask, and the long leg hangs down on the outside to the vessel to receive the liquor. In this position the finger is removed from the end of the long leg, and the liquor continues to flow through the syphon, as long as the short leg continues dipped in it. Instead of filling the legs with the liquor, some syphons have a pipe attached to the long leg, and turned upwards, by which a person sucking out the air, will make the liquor follow over the bend of the machine and flow as before. If the perpendicular height of a syphon from the surface of the water to the bent part be more than thirty-three feet, it will draw no water; for the weight of such a column of water is equal to that of a column of air reaching to the upper surface of our atmosphere. Mercury may also be drawn, on the same principle, by a syphon, provided the perpendicular height of the short leg do not exceed twenty-nine inches; because a column of mercury of this height, is equally heavy with one of water thirty-three feet high; mercury appearing by the table of specific gravities, given under hydrostatics, to be to water, as 13.57 to 1. One great advantage of the syphon is, that, being applied to the upper part of the liquor in the cask, the whole may be drawn off, without disturbing the sediment. Water in a close pipe, it was before observed, may be conveyed down into hollow ground, and will again rise nearly to the level of the source. But if an opening be made in the pipe, when in the lowest position, and a short upright pipe be fixed in it, the water will be thrown up to a height proportioned to the pressure in the pipe, and to the resistance of the air. In this way fountains or *jets-d'-eau* are formed.

The Pump. This the most common, and the most useful of hydrau-

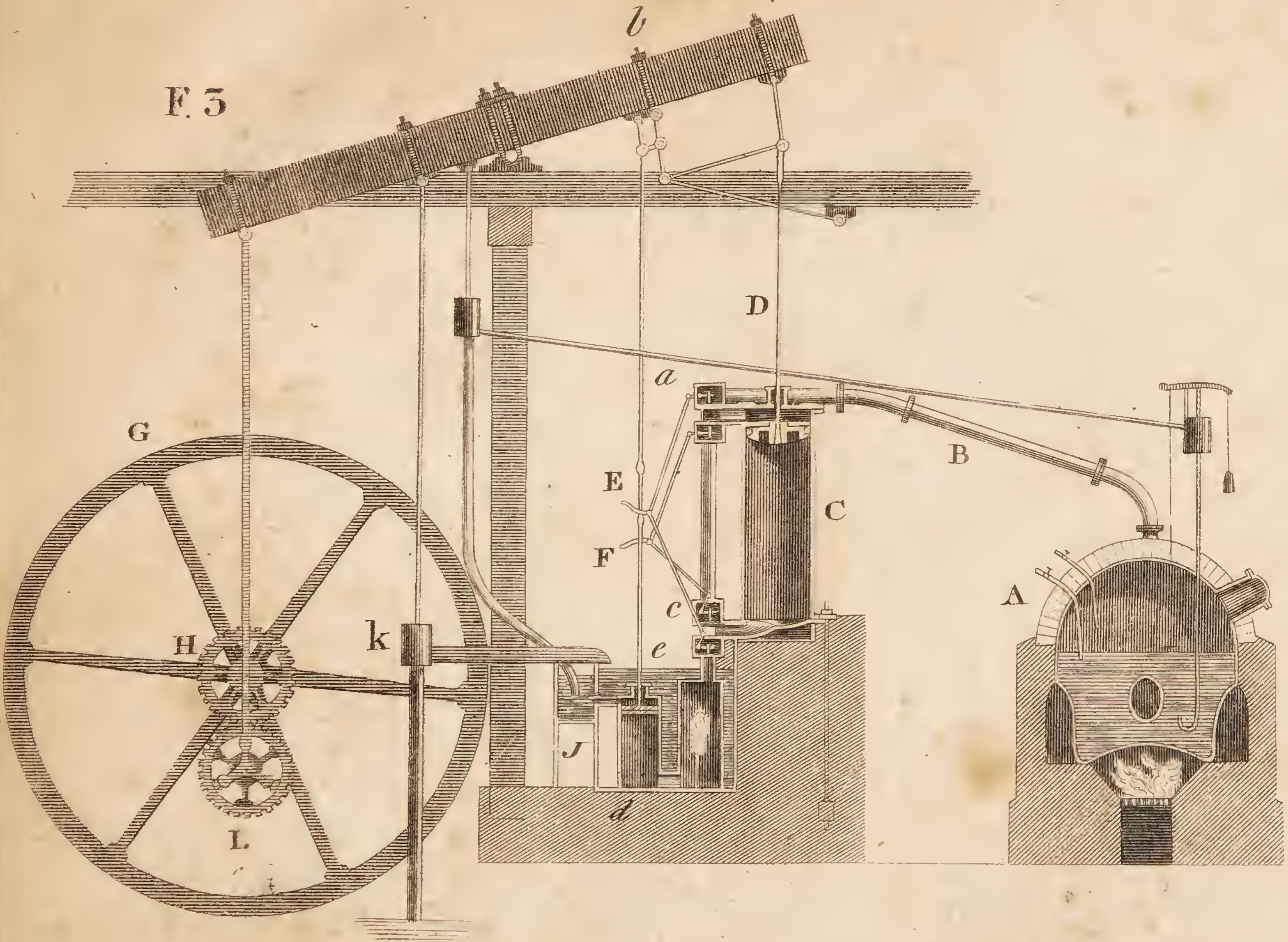
lic machines, is said to have been invented by *Ctesibius*, a philosopher of Alexandria in Egypt, about 120 years before the christian era; but, since the nature and action of the air have been understood, the pump, in its various applications, has been brought to great perfection. These machines are divided into sucking, lifting, and forcing pumps. The *sucking* pump was so named, because it was supposed, by its action, to draw up the water in the pipe. This notion is however now known to be erroneous; the water in the pipe being forced to rise by the pressure of the external water in the well or cistern, as is explained under the head of *Pneumatics*. Suppose a long pipe perfectly air-tight be closed at one end, and then filled with water; if the open end be turned down into a vessel of water, the fluid in the pipe will run into the vessel, until the upper part come to about thirty-three feet above the surface of the water in the vessel, and there it will stop. If instead of water a small glass tube or pipe three feet long, and closed at one end, be filled with mercury or quick-silver, and then placed upright in a vessel of mercury, the fluid in the pipe will run down until the upper part come to $29\frac{1}{2}$ or 30 inches above the surface of that in the vessel. The air having been excluded from both pipes, the water and the mercury have no air above them to counteract the pressure of that resting on the fluid in the vessel; consequently each is supported in the pipe, at such a height that its weight is equal to that of the external air. Hence we find, that a column of water thirty-three feet high, and one of mercury of twenty-nine or thirty inches high, are equal in weight to a similar column of common air. These heights of the water and mercury, are however subject to variations, according to the density and consequent pressure of the atmosphere. Those of water have been less observed than those of mercury, which has perhaps never been known to rise to thirty-one inches, nor to sink to twenty-eight inches; hence twenty-nine one-half inches may be taken for the medium height. The celebrated Italian philosopher *Galileo* was the first to observe that water could not be raised, by what was called suction, above thirty-three feet, and his pupil *Torricelli*, considering that mercury was nearly fourteen times heavier than water, employed that fluid, which accordingly stood at a corresponding height in the pipe of $29\frac{1}{2}$ inches. A square column of mercury, of 1 inch a side, and $29\frac{1}{2}$ inches high, weighs just 15 pounds; consequently the air presses with a weight of 15 pounds on every square inch of the surface of the earth, and 144 times as much upon every square foot. The common sucking pump, consists of a pipe of wood or metal open at both ends; in the pipe a rod is made to be moved up and down by the handle acting on a joint or crank. At the lower end of the rod is fixed a small circular box, called *the piston*, fitted with soft leather, so as just to fill the bore of the pipe, to prevent any air from passing down between the piston and the sides. In the middle of the piston, and on its upper surface is fastened, by a hinge on one side, a lid opening upwards like a trap-door. When the piston is pushed downwards by the rod, this light lid, or *valve*, is raised up by the resistance of the air below it, which consequently rises above the piston, and on drawing up the rod, the valve, from the resistance of the air above it, is closely shut down. The column of air in the pipe above the piston is thus raised up, while that below having now a large space to fill, becomes rarer and lighter than before; and the lower end of the pipe being

placed under the surface of the water in the well, no external air can come into the pipe to restore the balance. By each stroke of the piston therefore the air below the piston becomes rarer and lighter, consequently, the water in the well being less pressed upon within than without the pump, it must gradually ascend in the pipe, until it rise so high as to be touched by the piston in its descent. When it sinks into the water the valve is found upwards, the water rises above the piston which, when drawn upwards, causes the valve to shut, the water above it is prevented from passing down again and is therefore pulled up by the piston. By repeated strokes of the rod in this way, more and more water is collected above the valve; and at last it rises to the head of the pump, where it flows out for use. As a column of water thirty-three feet high, is equal to a column of air, the water under the piston cannot rise in the pipe above that height; and indeed, from the friction of the pipe and the variations of the weight of the air, water in the sucking-pipe is seldom raised above twenty-eight feet: but when it is once collected above the piston or bucket, it may afterwards be drawn up in the pipe to any height proportioned to the power employed. The water being thus raised by the alternate motions of the piston, the stream at the top must flow very irregularly. It is therefore convenient to have, at the head, a cistern to receive the water from the strokes, and having a small pipe in the side, by which the water will be discharged with a constant regular stream. The sucking-pump is usually made of two pipes, the upper part, called the *barrel*, is of a wider bore than the lower part or *suction-pipe*, which enters the well; and at the joining of the two is another valve, also opening upwards, which greatly assists in the working of the pump. This pump acts accordingly, not only by drawing off the air from the surface of the water in the pipe, but also by pulling up the fluid collected above the valve: in this case it acts as a *lifting-pump*. The *forcing-pump* acts upon a different principle. In the suction-pipe is a valve opening upwards, and a little above this valve is a pipe communicating with a vessel on one side. The piston of the pump is solid, and made to fit the bore exactly. Suppose this piston pushed down until it rest on the valve of the suction-pipe: if it be now drawn up, it will raise the air above it, and create a void below it: the air below the valve will now open it and fill the void, and at last the water will follow and rise above the valve, which, when the piston ceases to ascend, will close and keep the water from going back into the well. The solid piston being again pushed down, it will press upon the water above the valve, which can escape only through the side pipe into the reservoir. In the top of this reservoir is fixed a small pipe, through which the water will at last be thrown up, with a force proportioned to the working power of the pump. This power acts only by sudden jerks: but by a very ingenious apparatus within the reservoir, in which the spring of the air is employed, the stream from the pipe is made to flow with an equal and regular force. The common fire-engine is of this sort, and that used for watering gardens; only they have two working-barrels, producing a more equal and powerful supply of water. The various combinations and improvements of these three simple powers of a pump, are by far too numerous to be here mentioned. One of the most important is the pump for drawing the water collected in the hold of a ship. The many fatal accidents that happen to ships, from the choking of the

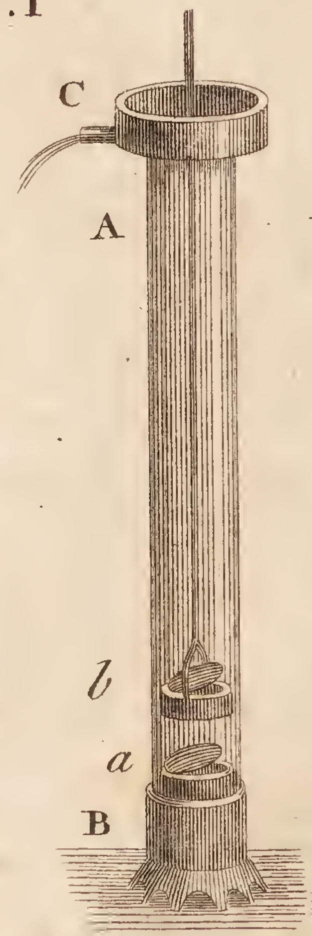
pumps, render the perfection of this machine an object of infinite consequence in sea affairs. The *chain-pump*, which is usually employed in British ships, consists of two square or cylindrical barrels, through which passes a chain, having a number of flat valves fixed upon it at proper distances; and the chain runs over a wheel at the end of the pump. These valves bring up each a quantity of water; and, as the machine is worked with briskness, a constant stream is made to rise in the pump. The disadvantages of this machine are, however, not much compensated by its being less liable to be choked with sand or other substances, than the sucking-pump. On this account *Buchanan's* pump was some time ago contrived, which, like the common pump, acts by the pressure of the atmosphere. By it the sand or other matters in the water are thrown out, without choking the piston or hurting the barrels; and should any obstruction happen, the valves are both within the reach of a man's hand, and may be speedily cleared: the machine may also be used to extinguish a fire on board the ship; and the same principle is applicable to a variety of uses on shore.

Steam-Engine. This machine, in its present highly-improved state, is one of the most noble and useful monuments of human ingenuity. It is now applied to various purposes; but as its original destination was to draw up water from coal-pits and mines, it may still be ranked among hydraulic engines. The first notice we have of this admirable machine is in a small book intitled *A Century of Inventions,* published in 1663 by *the Marquis of Worcester.* Thirty years afterwards *Captain Savary* obtained a patent for constructing steam-engines; which were afterwards much improved by *Newcomen,* &c. until at last, in 1762, *Mr. Watt* of Glasgow, since of Birmingham, turned his thoughts to the subject; in consequence of which, steam-engines are now brought as nearly to perfection as can reasonably be expected. The principles of the steam engine are in themselves simple; but it has required many trials and great ingenuity to bring them to act in the most beneficial manner. If water be heated in a close vessel, a few degrees above the point at which it would boil in the open air, it is then converted into steam or vapour, elastic uniform and transparent, not half the weight of common air, greatly exceeding in bulk the water from which it was produced and, on account of its elasticity or spring, capable of acting with great force on surrounding bodies. Suppose, in a vessel of boiling water, a frame of wood like a solid piston be placed, communicating by a metal rod, with one end of a beam or lever moving on a central support. When the water is sufficiently heated, steam or vapour will be formed which, having no other way to escape will, by its elasticity, press against the piston, and force it upwards. The end of the beam connected with the piston will of course be forced upwards, and the opposite end, which is made heaviest, will sink down. Suppose again, that when things are in this state, by the application of cold to the vessel containing the hot vapour, it be cooled and consequently condensed, the vapour will be once more brought back to its former state of water. This water occupying but a small space in comparison of the vapour, a great *vacuum* or void will be formed between the surface of the water and the piston, now standing at the top of the boiler. In this case the air will press forcibly on the upper part of the piston, and thrust it down within the boiler, until it again come into contact with the water, and the opposite end of the beam will be drawn up-

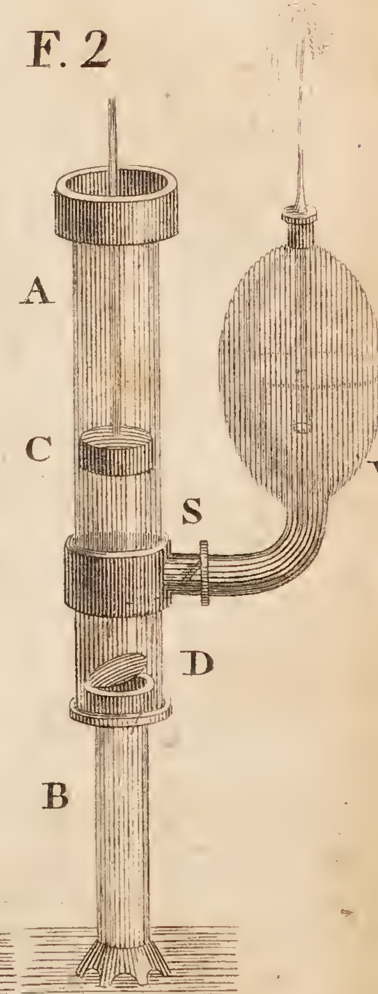
F. 3



F. 1



F. 2



wards. By the action of the fire fresh vapour is produced in the boiler, which forces up the piston, and makes the opposite end of the beam again descend; and by a second application of cold, the vapour is again brought back to water, a vacuum is formed in the boiler, the piston is pushed down by the air, and the beam-end again rises. By this repetition of heat and cold the beam is made to acquire a reciprocating motion, and at the opposite heavy end a piston-rod may be made to work as in a common pump. Simple as these facts really are, in constructing the machine, a multitude of important difficulties were to be surmounted; and it was by attention to these that Watt's engines have been brought to their present perfection. As his machines work by a double stroke, both up and down, it is necessary to employ not chains but rods fixed to the ends of the beam: to make these move perpendicularly very ingenious machinery was adapted, consisting chiefly of what are called the parallel-joint and the sun-and-planet wheels. By these contrivances a motion perfectly equable is given to the machine, by which it is now applied to purposes which formerly could be answered only by wheel-work. In various parts of England and Scotland, and in North America, passage-boats of large dimensions are made to go upon rivers and canals by means of steam-engines moving machinery; and that with great velocity, even against wind and tide. Important additions to Watt's engine have lately been made by Mr. Cartwright. To show the power of the steam-engine, it will be sufficient to observe that one of Watt's construction having a condensing cylinder thirty-one inches in diameter, and making seventeen double strokes in a minute, performs the work of forty horses working night and day (for which three relays, or 120 horses must be kept) and burns 11,000 pounds of Staffordshire coal every day. A cylinder of nineteen inches diameter, making twenty-five strokes of four feet each in a minute, performs the work of twelve horses, (that is to say, of thirty-six horses divided into three relays, each twelve at a time,) working constantly, and burns 3,700 pounds of coal in a day. A cylinder of twenty-four inches diameter, making twenty-two strokes of five feet, burns 5,500 pounds of coal, and is equal in power to the constant work of twenty horses. The ingenious Mr. Boulton of Birmingham applied the steam-engine to work the machine used in coining money, as now practised in the new mint lately erected on Tower-Hill, London. This admirable machine, by the help of only four boys, is capable of striking off thirty thousand pieces of money in the short space of one hour; besides which, the apparatus itself is so constructed as to keep an accurate account of the number of pieces struck off.

Explanation of Figures.

Platege *b* IIig. 1. is the lifting-pump, of which AB is the body or barrel, h:aiI. g small openings at the lower end to keep out stones or other th anhiat might injure the machine. At *a* is a valve opening upwards nF t is the piston, having also a valve opening upwards.— This piston is moved up and down by a rod. Both it and the lower valve must be under the surface of the water, which, when the piston is pushed down, shuts the lower valve, and rises above the upper. When the piston is drawn up, the water above it is lifted with it; and by repeating the motion, at last it rises to the top of the pump, and flows out by the spout C.

Plate III. Fig. 2. represents the forcing-pump, in which AB is the barrel, and C is the piston or forcer. At D and S are two fixed valves, so fitted as to allow the water freely to rise above them, but totally to prevent its falling back. When the piston is drawn up, the air below being rarefied, the water rises, and fills the space between D and S: but when the piston descends, the water has no other way to escape, but through the valve S into the strong capacious vessel V, closed at the top by a small pipe reaching nearly to the bottom. The air in the vessel being crowded into a small space by the water forced into it, acts reciprocally on the water, forcing it up in a continued stream through the pipe.

——— Fig. 3. is a section of Watt's improved stream-engine in which A is the boiler, B the steam-pipe conveying the steam to the cylinder C, in which works the piston D. The steam-valves are *a* and *c*. The condenser *e* is a separate vessel placed in a cistern of cold water, having a jet continually playing up within it. At *d* is an air-pump, worked by a rod from the great beam at *b*. To make the engine open and shut the steam and eduction-valves, levers are attached to them at E and F, which are moved by the piston-rod of the air-pump. At *k* is another pump worked by the engine, to supply cold water to the cistern, in which the condenser is placed. To communicate a rototary motion to any machinery to which the steam-engine is adapted, Mr. Watt's invented the sun-and-planet wheels GH and L, by which the alternate jerking motion of the beam is entirely avoided.

SECT. III.

PNEUMATICS.

Pneumatics are properly that branch of the science of Natural Philosophy, which treats of the properties of all sorts of air in general; but we employ the term, in common language, to express only the mechanical, and not the chemical or medicinal properties of elastic fluids in the form of air. Air in general is the fluid substance in which we breathe and live: it entirely envelopes our globe, extending to a considerable, but unknown distance from it, in all directions; together with the clouds and vapours floating in it, we call it the *atmosphere*. Air differs from all other fluids (substances of which the particles have very little cohesion, and are, therefore, easily separated from each other, even by the action of gravity) in these particulars: 1. It can be compressed into a space much more contracted than that which it naturally occupies: 2. It cannot be frozen or congealed into a solid body, as other fluids may be: 3. It is of a different density (that is, its particles are situated at different distances asunder) as it is more or less remote from the surface of the earth, decreasing in weight, bulk for bulk, the higher it extends: 4. It is elastic, or of a springy nature, so that if it be compressed, and again be set at liberty, it will return to its former bulk with a force equal to its weight. Being transparent in all directions, air must of necessity be imperceptible by our eyes; but in swinging the hand quickly up and down

or sideways, we feel distinctly that we are separating the parts of some substance; the feeling is just of the same sort, although much more feeble, as that perceived in moving the hand through water. A whip or small stick moved rapidly through the air, is evidently bent, and occasions a sound; showing by both that it meets with resistance from the air. The effects of a fan, and of fanners to clean corn, are too familiar to be noticed. If a bladder be blown up, and the neck left open, you may squeeze the sides together, and press it into any shape. If again it be blown up, and the neck tied so tight that no air can get out, you will find that no pressure can bring the sides together; and that no great violence will be necessary to make the bladder burst with a loud explosion. If the side of a full-blown bladder be pressed with the finger, a dent may be made in it: but remove the finger, and the dent will instantly disappear. These experiments clearly show that within the bladder is a substance elastic, and therefore capable of compression to a certain point, beyond which it will sooner break from its confinement than be forced into less space. The common bellows show powerfully the substantiality of air. Two boards are connected together by leathers made air-tight, and capable of stretching and contracting within certain bounds. At one end of the leather is fixed a pipe, and in the under board is a flap or valve opening inwards. When the bellows lie shut, but little air is within them; but if the upper board be a little raised, the air within, swelling into greater bulk, becomes too rare or thin and light to resist the pressure of the external air, which will of course rush in through the pipe and at the valve, which will be thus compelled to open inwards to give it admission. When the bellows are opened to the utmost, and kept in that state, the air without and within being now of equal density, no motion in it will take place. Begin now to press down the upper board: the air within being pressed together, will act upon the valve, shutting it close, so that no air can escape that way: it must therefore pass out through the pipe or nozzle in a stream more or less powerful as the boards of the bellows are pressed together with more or less quickness: and this violence of the stream, and the force reqnired to produce it, will leave no doubt that air is a real substantial body It may be proper to observe here, although a little out of its place, that common air being necessary to the burning of fuel, in kindling a fire, to place the nozzle of the bellows close to the grate, and to blow with violence, are very erroneous. A gentle stream of air coming from some moderate distance, will cherish the feeble spark, and the stream may be increased as the process of inflammation advances. Air at rest pressing, like all other fluids, equally in all directions, we can move in it as we choose, and are, therefore, insensible of its existence; but when it is in motion, it becomes perceptible, and is then called *wind;* the violence and dreadful effects of which, on land as well as on sea, are too notorious to require specification. To give the reader, however, some accurate notion, as far as can be done in the present work, of the rapidity and force of the wind, in different circumstances, the following table is introduced. In the fifty-first volume of the Philosophical Transactions of the Royal Society of London, are given the results of experiments, made by the late eminent engineer *Mr. Smeaton,* on the velocities of winds; to these is here added a column showing the force or impulse of the

wind, acting upon a surface of a square foot, erected perpendicularly to its current, and measured in pounds aviordupoise.

Velocity of wind.		Force on one square Foot in pounds.	Names of Winds.
Miles in one Hour.	Feet in one Second.		
1	1.47	.005.........	Hardly perceptible
2	2.93	.020	Light Airs
3	4.40	.044	
4	5.87	.079	Fine Breeze
5	7.33	.123	
10	14.67	.492	Brisk Gale
15	22.00	1.017	
20	29.34	1.968	Fresh Gale
25	36.67	3.075	
30	44.01	4.429	Strong Gale
35	51.34	6.027	
40	58.68	7.873	Hard Gale
45	66.01	9.963	
50	73.35	12.300	Storm
60	88.02	17.715	
80	117.36	31.490.........	Hurricane
100	146.70	49.200.........	Do. overturning Buildings tearing up trees, &c.

By this statement we see, that when the motion of the air, or the wind, is so gentle as to be hardly perceptible, its velocity is computed to be at the rate of one mile in an hour, or nearly one foot and a half in one second. If a board, one foot square, be hung up in the current, it will be acted upon by a force equal to five thousandth parts of a pound avoirdupoise, not quite two drachms. In a brisk gale the wind travels from ten to fifteen miles in the hour, or from fourteen and a half to twenty-two feet in the second. In the first rate of motion its force or impulse on the board is nearly as half a pound, but in the second rate it exceeds a whole pound. The most furious hurricane of the West Indies is computed to rush forward at the prodigious rate of 100 miles in an hour, or nearly 147 feet in a second; and its impulse upon a foot square of surface, opposed to its violence, is upwards of forty-nine pounds: that firmly-rooted trees, and well-compacted buildings, are unable to resist the assaults of such a wind, will therefore occasion no surprise: the miseries of the forlorn mariner, involved in its destructive course, may be better conceived than expressed.

Air-Pump. Air being a real substantial fluid, it may be drawn off from any vessel like any other fluid. This is done by means of the air-pump, a machine operating in the same way with a common lifting pump in water. The air-pump was first brought into effect by *Otto Guericke,* of Magdeburg in Germany, in 1654: but since his time, very material improvements have been made in the application

as well as the construction of the machine, especially by our countrymen Robert Boyle and Dr. Hooke. The air-pump, now in general use, is constructed in the following manner. On a strong square wooden frame, and near the right side, are erected two strong brass cylindrical pipes, or working-barrels. In each barrel is a rod and piston having a valve opening upwards. Between the tops of the rods above the barrel, is fixed a winch, with a pinion which works in teeth cut in the rods or racks; and by the motion of the winch backwards and forwards, the rods are alternately moved up and down in the barrels. Near the barrels on the frame is applied a brass plate, ground perfectly even, having, in the centre, one end of a brass pipe, of which the other communicates, through the frame, with the bottom of the barrels, and ending outwardly, where is a cock to open or shut it at pleasure. Upon this brass plate stands a glass vessel, bell-shaped, with the rim downwards, and ground so even that, when rubbed with grease, the glass may unite so closely with the plate, that no air can enter between them: this vessel is called a *receiver*. The receiver being thus fitted to the plate, and the cock at the outer end of the cummunicating-pipe being shut, the machine is ready for operation. Let one of the pistons be drawn up to the top of its barrel, and the other be pushed down to the bottom. By turning the winch, the top piston will be thrust down, and the bottom piston will be drawn up. The valves being light and easily raised, the air in the barrel will rise above the descending piston; and, as it rises, the valve shutting will bring up and discharge from the top of the barrel all the air above it. Turning the winch the contrary way, the other piston will be drawn up, and discharge a like quantity of air. In this manner, by the alternate action of the two pumps, the air in the glass receiver and the brass tube, will be exhausted; so much so, that unless the receiver be strong, it will not be able to resist the pressure of the external air, having no air within to counterbalance it. It is to be observed, however, that entirely to exhaust the air, or to produce an absolute vacuum, by the pump, is impracticable. Allowing it were possible to construct the whole machine, and to fit the pistons to the barrels, with such precision as that no air could force its way in; still, as in the descent of the piston, unless the air below the valve be sufficiently dense to lift it, and so rise above the piston, no more air can be drawn off. Hence it will be evident, that to produce a perfect void, or totally to exhaust the air from a receiver, must be beyond our power. When the receiver is first fitted on the plate, it may be removed with the same ease as it was placed; but if the air be exhausted, it cannot be taken off without a force equivalent to the pressure of the external air over its whole surface. *As light as air* is a common saying: air, however, is of greater weight than is generally supposed. Take a thin hollow copper ball, or a thin glass flask, such as is used to hold Florence oil: suppose each of these, or any other similar vessel, to hold a wine quart: weigh the vessel exactly when filled with air, and applying it to the air-pump, exhaust the air, stop up the mouth, and again weigh the vessel when empty. The difference between these weights will be found to be about sixteen grains, being the weight of a quart of air. The density and weight of the air are, however, liable to very considerable variations from different causes. When the mercury in the barometer stands at twenty-nine one half inches, the weight of

the air upon a square inch of the earth's surface is fifteen pounds; when it falls so low as to twenty-eight inches, the weight on a square inch is not quite fourteen one-fourth pounds, and when it rises to thirty-one inches the air will press on each square inch with a weight of fifteen pounds three quarters. Supposing the surface of the body of a middle sized man to measure fourteen square feet, or 2016 square inches, he sustains a pressure, (at the medium weight of air of fifteen pounds on each square inch,) of 30,240 lb. Troy, or eleven tons two cwt. eighteen one-half lb. But the air pressing equally on all sides, within the body as well as without, no action is produced upon the fibres, so as to derange them, but rather to brace them together, and keep each in its proper place, consequently no sensation of pressure or weight can be excited. The fish is no more exposed to be crushed by the weight of the water above when lying in the depths of the sea, than when within a few inches of the surface. In the surgical operation called *cupping*, a number of small shallow openings are made in the skin, but little or no blood follows the wounds. A cup or small vessel in which some tow or light combustible substance is set on fire, is inverted over the place. The fire consumes the air in the cup, which is then closely applied to the skin; and the pressure of the air being thus taken off from that part, while it acts with full force on all the other parts of the body, the blood is forced out through the small punctures made by the instrument.

As all the parts of the atmosphere gravitate or press upon each other, we can easily conceive why the air should be denser or more compressed near to them at a distance from the earth. Let a quantity of fine light wool be thrown gently into a pit until it be filled. The wool in the bottom, having the weight of the whole quantity to support, will be compressed into less thickness than an equal quantity lying in the middle of the depth of the pit, while that near the top will occupy nearly as much room as the light parcels as first dropped in. The same is the case with our air or the atmosphere: consequently, if we were to make experiments on the weight of the air, taken at regular equal distances upwards from the surface of the earth, this weight would be found to diminish according to a stated proportion. This proportion has been computed to be such that if the heights from the earth be taken in arithmetical proportion, the rarity of the air will be in geometrical proportion: or, in other words, if the height be doubled, the rarity will be as the square of the first rarity. If the height be tripled, the rarity will be as the cube, and so on. Gravity or weight being in proportion to the number of particles of matter, contained within a given space, as these particles are placed nearer to, or farther from, each other, the body they compose is said to be more or less *dense* or thick, and less or more *rare* or thin. The thinness or rarity of the air increasing as we rise in it, agreeably to the foregoing proportion, it follows that whatever be the rarity of the air on the surface of the earth, at a height of $3\frac{1}{2}$ miles the rarity of the air will be doubled, or its weight will be reduced to one half: at seven miles of height, the rarity will be four times greater, or the weight will be reduced to one-fourth of that on the earth, &c. This fact is not known from theory only, for it has been confirmed by experiments made on the most elevated mountains in the world; as on the summit of *Mont Blanc* in the Alps, which rises very nearly three English miles above the level of the sea.

The Barometer. The column of mercury supported by the pressure of the atmosphere in a tube devoid of air is of different heights according to that pressure, or to the weight of the external air ; hence the machine obtained the name of *barometer,* from Greek words signifying the *weight-measurer.* It was also observed, that variations in the length of the column of mercury, seemed to be generally accompanied by variations in the state of the weather : hence the machine was called the *weather-glass.* The barometer consists of a straight glass tube or pipe a quarter or rather one-third of an inch in diameter, and thirty-four inches long. It is *hermetically sealed* at one end (that is, the end is closed by melting the sides together) and made perfectly clean and dry. A quantity of the purest mercury is poured into the tube, and by placing a finger on the open end, when it is full, the tube is turned downwards, and sunk below the surface of mercury placed in a small bason. The finger being now removed, the mercury in the tube will sink down till it be in weight equal to that of an equal column of air pressing on the surface of the mercury in the bason. By this sinking, a space of four or five inches or so, will be left in the upper part of the tube, above the mercury, entirely free from air, and therefore a perfect vacuum is produced, in which the fluid may rise or fall without obstruction. The tube and bason are then attached to a frame, on the upper part of which is a portion of a scale of inches and tenths, accurately measured from the surface of the mercury in the bason.

The Thermometer. As the mercury may be influenced in its rise and fall, by the heat or cold, as well as by the weight of the atmosphere ; another instrument should be attached to the barometer, to indicate the variations of temperature in respect to heat and cold. This instrument, called a *thermometer,* from Greek terms signifying a *heat-measurer,* resembles the barometer in being a glass tube of a small bore, blown up at one end into a ball or bulb. The bulb and a part of the tube being filled with mercury, the other end is melted together. Mercury is employed in this instrument, because it expands or enlarges its bulk when exposed to heat, more equably than any other fluid. Of this instrument various kinds are in use ; but that employed in this country is *Fahrenheit's,* so called from the inventor of its scale. In measuring the degrees of heat, the standard points are those of freezing and boiling water, which are constantly the same in all parts of the world.—The point of the tube at which the upper surface of the mercury stands, when immersed in freezing water, is marked on the scale thirty-two parts or degrees, and observing to what height the mercury rises, when immersed in boiling water, the distance between the two is divided into 180 equal parts, which added to thirty-two, give 212 for the height at the heat of boiling water in the open air. Water cannot be made colder in the open air than thirty-two parts or degrees, because, at that temperature it ceases to be a fluid, being converted into ice ; nor hotter than 212 degrees, because at that temperature it loses the form of water, and is converted into vapour or steam. The reason why the temperature of freezing water was fixed at thirty-two degrees, was, that Fahrenheit found the most intense cold he could produce was by mixing snow and salt together. Placing the thermometer in this mixture, the point to which the mercury sunk, he marked O, as the beginning of his sclalc ; and the space between this point and that at which the mercury stood, when placed in freezing water, was found

to contain thirty-two of those equal parts, of which 180 filled up the space between the points of freezing and boiling water. But much more intense cold can now be produced, than was formerly imagined by the mixture of substances which dissolve rapidly; such are neutral salts dissolved in water, diluted acids and some neutral salts, snow or pounded ice, and some salts; and a number of equal parts or degrees being reckoned downwards on the scale from O or zero, the degress of cold may be measured as those of heat upon the upper part of the scale. A mixture of eight parts of sulphat of soda (formerly called Glauber's salts) with five parts of muriatic acid (or acid of sea-salt) will sink the mercury in the thermometer from 50 dregrees to O; that is, will produce a cold 32° below that of freezing water. If 2 parts of snow or pounded ice be mixed with 1 part of common salt, the mercury will sink to 5° below O, and the temperature is then expressed thus—5°, the algebraic sign—or *minus* denoting that the degree of cold is *less* than that at the beginning of the scale. If three parts of muriat of lime (or fixed sal-ammoniac) be mixed with 2 parts of snow, the fluid in the thermometer will sink from 32° above O to—50° below it; but the most intense cold hitherto known has been produced by mixing 10 parts of sulphuric acid (or oil of vitriol) diluted, with 8 parts of snow, by which the fluid will sink to—91° or 123 degrees below freezing water. To measure the intenseness of cold of this sort, spirits of wine or some essential oil must be employed instead of mercury, which itself freezes and becomes solid when the temperature falls to thirty-nine degrees below O. Nor can mercury measure heat greater than 660 degrees, for there it boils and is converted into vapour. The thermometer in general use in France and other parts of the continent, was invented by the celebrated naturalist *Réaumur*: in it the point of freezing water is the beginning of the scale or zero, and the space up to boiling water is divided into eighty equal parts. Later philosophers abroad have divided that space into 100 equal parts, whence the thermometer is said to be *centigrade.* As considerable embarrassment is often occasioned by these different modes of measuring the temperature of the air and other bodies, the following rule for converting Reaumur's degrees into Fahrenheit's will be useful. Multiply the number of degrees of heat shown by Reaumur by 9, divide the product by 4, and to the quotient add 32, and the sum will be the degrees on Fahrenheit; and by reversing the operation degrees on the latter will be turned into those on the former. On our common thermometers different points of heat are marked, as at thirty-two degrees freezing; at fifty-five degrees temperate, at seventy-six degrees summer heat; at ninety-eight degrees blood-heat; at 112 degrees fever-heat; at 176 degrees alcohol (spirit of wine) boils; and at 212 degrees water boils.

How far our atmosphere may extend beyond the surface of the earth is unknown; it is observed, however, that the sun's rays passing through it at an elevation of forty-five degrees undergo no sensible refraction; so that the air at that point must be at least inconceivably rare. Nevertheless, meteors (balls of fire and shooting stars as they are called,) have been observed at an elevation of seventy or eighty miles, and most probably have been within the bounds of our atmosphere. Clouds seldom rise above 2½ miles above the level of the sea; for there the atmosphere is equally rare with themselves.

If a lighted candle be placed under the receiver of the air-pump, it will burn as long as the air is sufficient for its support, and when it goes out, the smoke will mount up and remain in the top of the receiver like a cloud. If now the air be extracted by the pump the smoke will gradually sink down to the bottom of the receiver, leaving the top perfectly clear. This experiment exhibits the cause of the rise and fall of clouds and vapours in the atmosphere, and that smoke is not devoid of weight. A piece of wood floats upon water; yet no one ever concluded wood to possess no real weight or gravity.

Air differs from water and other liquid substances in this particular, that to whatever quantity it may be reduced and extracted, the remainder in the vessel will always completely fill it. This is caused by the very great elasticity or spring of its particles, which makes them depart from each other in all directions, in proportion as pressure is removed. If three quarts of air be pumped out of a vessel holding a gallon, the remaining quart will expand over the whole space of the vessel: if on the contrary the vessel be filled with water, and three quarts drawn off, the remaining quart will just occupy the same space as when the vessel was full. In this manner air may be rarified or made thin: in a similar way, on account of its elasticity, it may be condensed or made thick, and be compressed into less space than it usually occupies. The machine by which this is done is called a *condenser*: it consists of a brass barrel containing a piston, with a valve opening downwards; so that when it is drawn up the air above passes through it, and when it is pushed down the valve shuts, and the air below is forced through a valve in the bottom of the barrel into a tube communicating with the receiver placed on the frame. Thus at every stroke of the piston more air is driven into the receiver, made of very thick strong glass, and kept down upon the plate by a strong wooden frame and screws. It is by the strong spring of air, when greatly condensed, that the air-gun works. A hallow ball, into which a great quantity of air has been forced, is so connected with the lock, that, when the hammer moves, a portion of the air rushes into the barrel and expels the bullet with very considerable force. The air in the ball may be sufficient for several successive discharges; but as the air becomes at each rarer and rarer, this force, it is plain, will proportionably decrease.

Winds. Water in motion in a current is a river, so air in motion becomes wind. If the air were uniformly of the same density, at the same height, the lighter parts always resting above the heavier, the lateral pressure being equal in all horizontal directions, the air would then always be at rest. On the other hand, if any portion of the air be heavier than the rest, it will descend, or if lighter it will ascend, until the balance be restored; whatever cause therefore alters the density of the air, must of course cause a motion in it, or wind. The density of air is changed by compression and heat; its elasticity or spring is increased by moisture; and electricity may have some effect of the same kind: but the principal cause of wind is certainly heat, by which the elasticity or repulsive power of the particles of air being increased, they retire farther and farther from one another. By this process the number of particles in a given space being diminished, the total gravity is also lessened; the thin or rare heated air is therefore obliged to give way before the pressure of the adjacent denser cold air, and a motion or current, that is wind, is produced, more or less powerful in propor-

tion to the different densities of the different kinds of air. The different winds are denominated from the points of the compass from which they blow; thus a north wind blows south, and an east wind blows west. They are also divided into variable and trade winds; the latter being subdivided into permanent and periodical. *Permanent trade-winds* blow constantly from the same point, or at least they are subject to very little variation. *Periodical or shifting trade-winds,* otherwise called *Monsoons* (from an Asiatic term signifying *seasons*), blow for a certain time in one direction, and then change to blow from the opposite point for a certain time. *Variable winds,* blow occasionally from every quarter of the heavens, without any regularity or uniformity of duration or strength.

The air over that part of the earth where the sun is vertical, is by his rays greatly heated and rarified; it therefore rises, and the adjacent cool air rushes in to supply its place. In consequence however of the earth's daily rotation on her axis from west to east, the sun apparently moves in the contrary direction; the rarified air will therefore move from east to west, and an easterly wind will be excited in the regions about the equator. Since the same places are brought round under the sun once every twenty-four hours, the air is not wholly cooled during the night, and thus a constant stream of air or wind from east to west is maintained. From the equator to about thirty degrees of latitude on each side, the wind blows from the eastward, but drawing more from north-east and south-east, in proportion as the place is situated more or less towards the north or the south of that line. This is the general state of the trade-winds, so called because they are of great service to commerce, by forwarding vessels on their voyages. Within the limits of the trade-winds, their direction, from local causes, is found to deviate considerably from the proper east; sometimes indeed even to the opposite quarter. Thus upon the coast of Guinea in Africa, although within the tract of the trade-winds, the wind blows from S. W. to N. W. The cause of this is, that the soil of that coast being in general sandy, it becomes extremely hot by the sun's rays; which greatly rarifies the air over the land, and then the cooler sea-air rushes in from the south and west to supply its place. At that part of the sea where this change of direction is perceived, there is generally a calm; and the air moving away east and west, what remains is unable to support the vapourse there collected, which accordingly fall down in frequent torrents of rain, so much so, that those parts are commonly called *the Rains.* By the Spaniards and Portuguese, they are called the *Ladies' sea,* because gales of wind are there very rare: to the mariner, however, such calms are much more distressing than a gale, because they retard his voyage, and occasion a great waste of time and provisions to no purpose. The periodical trade-winds or monsoons blow regularly, during six months, from one quarter, and during the remaining six months from the opposite quarter. These winds prevail chiefly in the ocean on the south of Asia; for those countries lying on the north side of the equator, are greatly heated in summer, which occasions the wind to set in northward from the sea; but in the winter months, the air over the sea is more heated, and the wind again sets southward from the land. The position of the coasts gives particular directions to these winds; but the Indian monsoons usually blow from the S. W. during our summer, and from the N. E. during our winter hence ships, going to, or coming from

India, know at what times of the year to fall in with these regular winds. In the warmer regions of the world, and even in the southern parts of Spain, Italy, Greece, &c. the land, in summer, is so much heated as to create a current of air to it from the sea; but in the night time the land is cooled and the air again returns to the sea. These periodical changes are called the land and the sea breezes; and they are extremely useful: for they carry a ship into the land in the day-time when light is necessary, but they carry her out to sea in the night time, when light is less necessary to guide her course. The sea breeze generally lasts from ten in the morning to five or six in the evening; when the land-breeze beginning about seven, lasts to eight in the following morning. There is another kind of periodical, but irregular, wind, which blows from the western coasts of Africa towards the sea. By the other nations of Europe this is called simply a NE. wind; but by our seamen it is called the *harmattan*, a corruption of aherramantah, the name given by the natives of the coast. This extraordinary wind comes on at all times of the day, and in all states of the weather; and it continues from a day or two, to fifteen or sixteen days; returning three or four times every season, and blowing with much the same force as the common land and sea-breezes. This peculiar wind is always accompanied by a fog or haze, and by extreme dryness; so that vegetables of every kind are very much injured, and most productions of the garden are destroyed. It is a remarkable property of this wind, that although so prejudicial to vegetable, it is highly conducive to animal health. Persons labouring under agues and dysenteries generally recover during a harmattan: it stops epidemic diseases, even the small-pox; and infection is not then easily communicated even by art. To some distance beyond the limits of the general trade-winds the wind is W. or between that and SW. without the northern limit; and between W. and NW. beyond the southern limit. In other parts of the temperate, and in the frigid zones of the earth, the wind is always fluctuating and changing from one point to another, without any regard to either direction or velocity. Whatever may be the cause of winds, and of their changes, it is ascertained that the cause exists in the quarter *to* which, and not *from* which, they blow. To understand this, we may refer to a common fact in the motion of water, equally a fluid with air, and subject to the same laws. Let us suppose a long canal of water, stopt at one end by a sluice. Until the sluice be opened, the water all over the canal is at rest; but when it is opened, the nearest water moves first through the sluice, then the water next farther back, and so on later and later as the distance from the opening increases; and, last of all, the water at the opposite end of the canal comes to be in motion. So that if the canal lay from E. to W. the water at the W. end would be setting westward, long before that at the E. end began to move.—Hence it is plain that, in ordinary cases, a wind blowing from E. to W. will begin to be felt in the western part of its course before it be felt in the eastern. In mountainous countries, the winds generally rage with the greatest violence; but the inhabitants are able, from certain appearances of the clouds, and other circumstances, pretty accurately to foretel the arrival of great changes in the weather. Thus, at the town of the Cape of Good Hope, in the southern extremity of Africa, certain motions and appearances of the clouds, upon the precipitous hills in the environs, give indications of approaching gales of wind which

blow with great violence, and frequently cause great disasters among the shipping in the bay.

A *whirlwind,* in the form of a column of smoke, or like a trumpet, having the wide end upwards, is formed by the air of a certain space rushing in from every quarter to a centre, whence ascending with great rapidity, and with a whirling motion, it overturns every thing in its way, tearing up trees, destroying buildings, shipping, &c. The whirlwind and the water-spout arise from the same cause, only that the whirlwind being formed on land, is usually composed of air alone, but the water-spout being formed at sea, is therefore composed of water.

The most dreadful of all winds, relative to its effects on men and other animals, is the *Samiel,* peculiar almost to the sandy deserts of Arabia, where it prevails from the NW. quarter, in July and August. In some years it does not blow at all; but in others it appears six or eight times, seldom, however, continuing longer than a few minutes at a time, and passing along with the rapidity of lightning. The Arabians and Persians, who are liable to be overtaken by this pestilential wind, are warned of its approach by a thick haze, like a cloud of dust rising on the horizon. As soon as this appears, the unhappy travellers throw themselves with their faces on the ground, and continue in that position till the blast be gone by, which is very speedily the case; but if this precaution be neglected, and the full force of the blast be received, death instantly ensues. In the south of Italy, and other parts of the Mediterranean coasts, the hot suffocating *Scirocco,* or SE. wind, is extremely inconvenient, notwithstanding it be cooled in traversing the sea, from the burning sands of Africa.

From the registers of the weather, kept by order of the Royal Society of London, the average of winds blowing there, for ten years was as follows:

Winds.	*Days.*	*Winds.*	*Days.*
South-west	112	South-east	32
North-east	58	East	26
West	53	South	18
North-west	50	North	16
			365

From this it appeared that the SW. wind blew nearly one-third of the year, and was very frequent in July and August; the NE. prevailed in January, March, April, May, and June; the NW. from November to March. On the other hand, on the great continent of the United States of North America, the NW. blows for 120 days in the year, the NE. for the same number; the E. for sixty days: and the remaining sixty days are distributed among the winds of the SE. and SW. quarters.

Of predicting the Weather. Amid the various objects of the pursuits of natural philosophers, the foretelling of the weather which may at any time be expected, seems hitherto to have been the least under their command. No fixed rules for this purpose have ever yet been discovered; yet from the multiplied observations of many ingenious and scientific men, made with the greatest care and impartiality, several general conclusions have been drawn, from which approaching changes in the weather may, with tolerable accuracy, be foretold. In this ope-

ration, the chief assistance is drawn from the barometer, which, on this account, is commonly called the weather-glass. The mercury seldom stands still for any length of time; but is continually rising or falling; and by such variations in its height, furnishes general maxims for judging of alterations in the atmosphere. Of these rules the following are, perhaps, the most accurate: 1. The rising of the mercury in the tube of the barometer announces, in general, fair weather, and its falling, bad weather, according to the season, as rain, wind, snow, &c. 2. In extremely hot weather, the falling of the mercury foretels thunder. 3. In the winter months, the rising of the mercury presages frost; and in frosty weather, if the mercury fall a quarter or half an inch or more, a thaw will almost certainly follow. 4. If bad weather happen almost immediately after the sinking of the mercury, it will not last very long. 5. In bad weather, when the mercury rises fast and high, and continues to rise for two or three days before the bad weather be over, then a continuance of fair weather will probably follow. 6. In fair weather, when the mercury falls for two or three days or more, then a good deal of wet may be expected, and probably high winds. 7. The unsettled motion of the mercury denotes uncertain and changeable weather. After all, in our observations, it is not so much the real height of the mercury, as its motion up and down, on which we ought to depend; at the same time that it will be in constant ascent and descent, for weeks together, without any sensible alteration taking place in the state of the weather.

Besides the barometer, other instruments are necessary for the meteorologist, viz. the *thermometer*, the *hygrometer*, and the *pluviometer*, or *rain-gauge*. The thermometer has already been described: the hygrometer serves to ascertain the quantity of moisture, or the degree of dryness, in the air, agreeably to the import of the name in the Greek language. These instruments are of various constructions; some being of strings of hemp, which shorten in moist weather, and lengthen in dry. Others are made of the beard or awn of the wild-oat, which, by twisting and untwisting in moist or dry weather, moves a hand or index attached to it: others again are made by balancing a large piece of sponge against a weight; in damp weather the sponge imbibes the moisture, and becomes too heavy for the weight; but in dry weather it returns to the equilibrium. In this manner are constructed the Dutch toys called weather-houses. The rain-gauge points out the quantity of rain falling on each square foot of the earth's surface in a given time. A very convenient one is made of a hollow cylinder, spreading out, as a funnel, at the top. In the cylinder is placed a light and slender wooden stem, fixed to a ball of cork, sufficiently large to float on water with the stem upon it. The cylinder is then placed in the open air, where the rain may fall freely into it, which will float the cork, and the inches and fractions marked on the stem, will show, by its rising above the funnel, the depth of water fallen into the cylinder in any given time. At each observation, the water is let off by a cock in the bottom of the cylinder, and a correct list of the depths at each observation, will give the total amount of rain fallen in a month, a year, &c. at any given place. In using this rain-gauge, the diameter of the cylinder should be four inches, and that of the funnel twelve inches. Now as the areas of these plane figures are to one another as the squares of the diameters, the area of the funnel is to that of the cy-

linder or tube, as 144, the square of 12, to 16 the square of 4: that is, as 9 to 1. If then the water in the tube be raised 9 inches, the rain fallen on the surface of the funnel, which is the true gauge, will be raised only one inch. Hence, if the stem be raised 1, 2, 3 inches, or so, the depth of rain fall on a foot square, will, by $\frac{1}{9}$, $\frac{2}{9}$, $\frac{3}{9}$, &c. of an inch. A very good common gauge consists of a funnel, containing, at the opening, an area, of exactly ten square inches, which is set in a common bottle. The water collected in the bottle is weighed, and for every oz. of water, 173 thousandth parts (more than $\frac{1}{6}$ of an inch) are to be allowed for the depth. Thus, if in a given time, 10 ounces of water be collected in the bottle, this quantity multiplied by the decimal fraction, .173 will give 1.73, or nearly $1\frac{3}{4}$ inch of depth of rain fallen. The reason of this is, that a gallon of wine measure of rain water, contains 231 cubic inches, and weighs 8 lb. $5\frac{2}{3}$ oz. or $133\frac{2}{3}$ oz. consequently, every ounce of water may be estimated at 1.728 or 1.73 cubic inch. But as the area of the funnel contains 10 inches, the depth of water on each will be one-tenth of that quantity, or .173 of an inch.

The quantity of rain that falls in different countries, and even in different quarters of the same country, is very different. In our island the quantity of rain that falls on the eastern coasts is much less than that which falls on the western coasts. The same fact is found in Ireland, although the quantity falling in that island, in general, greatly exceeds what falls in Britain.

The following table exhibits the observed depth of rain, in English inches, fallen in the course of a year, at various places, abroad as well as at home, proceeding from the least quantity to the greatest: the whole extracted from the best and latest authorities.

Table of the annual Fall of Rain.

Places.	Inches and Tenths	*Places.*	Inches and Tenths
At Upsal, in Sweden .	16.7	Ferriby, York.	26.6
Bridgeford Notts . . .	17.	Chichester	26.8
Wittemberg, in Germany	17.	Ulm	27.
Petersburgh, Russia . .	17.2	Algiers	27.
Diss, Norfolk	18.7	Chatsworth, Derby . .	27.8
Upminster, Essex . . .	19.5	The Hague	28.4
Carlisle, one year . . .	20.2	Delft	28.6
Paris	20.2	Bristol	28.6
Berlin	20.6	Bridgewater	29.3
Rome	21.3	Abo, in Sweden . . .	29.3
Edinburgh	22.	Leydon	30.2
Dublin	22.2	Glasgow	31.
South Lambeth, Surry .	22.7	Madeira	31.
London	23.	Minehead, Somers. . .	31.3
Oundle, North^{n}. . . .	23.	Manchester	33.
Lille	24.	Middelbury	33.
Lyndon, Rutland . . .	24.3	Zurich, Switzerland . .	33.1
Utrecht	24.7	Exeter	33.2
Haerlem	24.7	Liverpool	34.4
Kimbolton, Hunt. . . .	25.	Padua, Italy	34.5
Norwich	25.5	Sienna, do.	35.2
Fyfield, Hants	25.9	Venice	36.1

Places.	Inches and Tenths.	*Places.*	Inches and Tenths.
Langholm, Scotland . .	36.1	Pisa, Italy	43.2
Selborne, Hants . . .	37.2	Plymouth	46.5
Dover	37.5	Charleston, N. America .	50.9
Lyons	39.4	Garsdale, Westmoreland .	52.3
Lancaster	40.3	Kendal, do.	59.8
Ludgvan, Cornwal . .	41.	Keswick, Cumberland .	67.5
Dordrecht	41.	India, sometimes . . .	104.
Townly, Lancas. . . .	41.5	W. India Islands do. .	126.

Without entering on a consideration of the peculiar circumstances of the situation of individual places, such as their vicinity to the sea, lakes, or rivers, or to lofty mountains which attract the clouds, it may be observed, that the mean annual fall of rain is greatest at the equator, and decreases gradually towards each pole. Thus, on an average, the rain falling in

Grenada, West Indies	N. Latitude	12.°00′	is 126 inches.
Cape François, St. Dom.		19.46 . .	120
Calcutta, Bengal		22.35 . .	81
Middle of Italy		42.00 . .	39
Mean of England		53.00 . .	32
Petersburgh, Russia		59.56 . .	17

But on the other hand, the number of rainy days is smallest at the equator, increasing proportionally to the distance of the place from it. Thus from N. lat. 12° to 43° the mean number of rainy days is 78, from 43° to 46° it is 103; from 46° to 50° it is 134; from 50° to 60° (including England and Scotland) it is 161. The number of rainy days is often greater in winter than in summer; but the quantity of rain is greater in summer than in winter. At Petersburgh in Russia the number of snowy or rainy days in winter is 84; yet the quantity of water is but five inches: whereas in summer the number of rainy days is nearly the same; but the quantity of water is above eleven inches.

In speaking of geography it was observed that the periodical swelling and sinking of the sea, or the tides, were produced by the attraction of the sun and moon on the waters, and that these risings and fallings were always greatest when those two heavenly bodies were in conjunction, somewhat smaller when they were in opposition, and least of all when lines from each met in a right angle at the earth. Hence the waters were the most attracted when the moon was new, less so when she was full, and least of all when she was in the first and third quarters. But at the equinoxes of March and September, when the sun and moon are in the plane of the earth's equator, the tides rise higher than at any other period of the year. Now the air being a fluid much lighter than water, it must be more affected by the attraction of the sun and moon, when she is new or full, and at the equinoxes, than at any other times. This is confirmed by observation, though neither to the extent nor with the punctuality which general opinion would warrant: for at the new and full moon changes in the

atmosphere not unfrequently take place; and the violence of the equinoxial gales is but too well known to the mariner.

According as the state of the atmosphere is more or less disturbed, the appearance of the heavenly bodies will be more or less altered.—Thus, if the moon appear paler than usual, or be surrounded by a halo or circle, rain will probably soon come on: several circles about the moon indicate wind. The same remarks apply to the sun. When the moon appears red, or if her horns be blunt, wind may be expected from that corner to which the bluntest horn is directed. A red circle about the full moon also betokens wind. In observing the rain-bow, if the blue and yellow parts are very bright, or if all of it vanish at the same time, it will be fair weather: if the bow appear broken in several places, tempestuous weather may be expected. A rain-bow in the morning is proverbially the sailor's warning. When the sky is of a fine blue colour, without any clouds, it will continue to be fair weather: but if it be of a very dark blue, clouds will be formed, and wind rain or fog will soon follow. When the sky appears very much clouded for some time, without rain, it generally first clears up, and then changes to rain. If the clouds in a summer evening gradually diminish, and at last vanish, it will be fine weather; but if the clouds increase, and small clouds be observed to move swiftly under the great ones, rain will soon ensue: or if the clouds assume a dark colour, thunder may be expected. If the clouds in the west, at the time of sun-set, be tinged with light red and yellow: or if there be no clouds, and the sky, in the same quarter, be of a beautiful red and yellow, it will be fine weather: but if the setting-sun look pale, or if the clouds then change to a dark red, and so continue, rain will come on. Clouds tinged with dark red, in the quarter opposite to the sun, whether at his rising or his setting, denote wind. In winter when large clouds are observed, with white edges, and a strong blue sky above them, it will be hail or snow, which however may perhaps be dissolved into rain before they come down to the ground. When two or more layers or strata of clouds are seen moving in different directions, rain generally follows. Many small clouds pretty high, and others appearing at the same time, in form of fleeces of wool, denote wind. A small black cloud in a clear sky, or several small clouds collecting near one another, are an indication of wind from the quarter from which the clouds move: also if the clouds are observed to spread out like rays from a point in the horizon, wind will come from that point, and in some cases from a point directly opposite to it. When the smaller stars are suddenly obscured, wind or rain may be expected; and the meteors, commonly called falling or shooting stars, usually forebode wind. The appearance of a wind-gall, that is, of a portion of a rain-bow, broader than the arch when entire, is an indication of an approaching gale. The *Aurora borealis*, or northern lights, called also streamers and merry-dancers, may generally be considered to announce wind from the SW. quarter, attended with hazy weather and small rain, the gale coming on 24 or 30 hours after the appearance of the lights. A considerable change of the wind commonly brings on a change in the weather.

From a great number of meteorological observations made in England for a century back, a number of probable conjectures on the

weather have been drawn, of which the following are the principal.—When there has been no storm before or after the spring equinoxes, the ensuing summer is generally *dry,* at least five times out of six. When a storm happens from any easterly point, either on the 19th, 20th, or 21st of March, the succeeding summer is generally *dry,* four times, at least, in five. When a storm arises on the 25th, 26th, or 27th of March, and not before, in any quarter, the succeeding summer is generally *dry,* four times out of five. If there be a storm from SW or WSW. on the 19th, 20th, 21st, or 22d of March, the succeeding summer is generally *wet,* four times in five. A moist autumn and mild winter are generally followed by a cold and dry spring, which greatly retards vegetation. If the summer be remarkably rainy, it is probable that the ensuing winter will be severe; for the unusual evaporation will carry off the heat of the earth. Wet summers are generally attended by an unusual quantity of seed on the white-thorn and dog-rose bushes. Hence the unusual fruitfulness of these shrubs is a sign of a severe ensuing winter. The appearance of cranes and birds of passage early in autumn, announces a very severe winter; for it is a sign that it is already set in in the northern countries of the continent. When it rains plentifully in May, it will rain but little in September; and, on the contrary, when May is dry, September will be wet. When the wind is SW. during summer or autumn, and the temperature of the air is unusually cold for the season, to both the feeling and the thermometer, and the mercury in the barometer keeps low, then much rain may be expected. Violent temperatures, such as storms of wind and great rains, produce a sort of critical change in the atmosphere, from which arises a constant temperature, good or bad, lasting for some months together. A rainy winter forebodes an unfruitful year; and a severe autumn announces a windy winter.

From our general ignorance of the causes of the great revolutions in the atmosphere, and our very confined powers of observation, the foregoing, and all similar rules, may be liable to many exceptions: from them, however, some hints and warnings may be drawn for the service of the *husbandman* and the *seaman,* two classes the most particularly interested in forming a correct prognostication of the weather. On such a subject scientific certainty is not to be obtained; but at the same time, the resultof general experience will be much more satisfactory than that of the worthy gentleman who, from his early days, had kept a regular journal of the state and changes of the weather; and at last, in his fourscore and tenth year, made this notable discovery *that the weather was changeable.*

Clouds, rain, snow, hail, mist, &c. belong to various branches of natural history and philosophy, particularly to hydrostatics and pneumatics; in this place, therefore, some brief observations on their nature may be introduced.

The change of solid bodies into liquids is now known, from the sagacious researches of the late *Professor Black* of Edinburgh, to be brought about by the combination of the solid with a certain quantity of the cause of heat, or *caloric,* as it is now termed. But there is another change still more remarkable to which they are liable by the action of heat. Almost all liquids, when heated to a certain temperatur, gradually put on the form of a fluid, elastic and invisible like pure air, and endowed with the same mechanical properties. Thus water by being

is converted into steam, which is invisible, so long as it retains all its heat. Thus the steam from the spout of a boiling tea-kettle is invisible for a short distance from the mouth; and only becomes visible in consequence of condensation in the cooler air. Steam is equally elastic with air; and a given quantity of water converted into steam is so prodigiously enlarged in bulk, as to fill a space 1800 times as great as that of the original water. Steam is lighter than air, as 10 to 12 according to some naturalists, or as 10 to 14 according to others. When the heat is a little diminished the particles of water unite together, and form small hollow globes or bladders, constituting what is thence called vesicular vapour. This vapour being exactly of the same specific weight with atmospheric air, it floats about in it under the name of clouds when greatly elevated, and of fog or mist when low on the surface of the ground. That clouds and fogs are of the same nature, has been ascertained by travellers in balloons; but it is a matter of constant experience to persons who visit the upper regions of the Alps in Switzerland, and other mountainous tracts. The vallies are screened from the sun by horizontal ranges of clouds, stretching across from mountain to mountain. As you ascend the slope, you approach and at last enter what appeared as a cloud from below, but what now shows itself to be in fact a thick penetrating fog or mist. Mounting still higher, you at last make your way up and through this stratum of vapour, and on ascending above its higher surface, you perceive the sun shining in all his vigour and brilliancy, illuminating the ridges and summits of the mountains, which now appear like islands seated in the midst of an ocean of resplendent vapour.

Different fluids, and even certain solids, are convertible into invisible vapour, at different degrees of heat or temperature. Some as water are gradually changed into vapour at every temperature, while others continue fixed until the heat arrive at a certain point. Water is converted into steam at a boiling heat, or 212 degrees of Fahrenheit's thermometer. But if an open vessel filled with water, and exposed to the common air, be examined, the water will be found daily to decrease, and at last totally to disappear. Alcohol or pure spirit, ether and volatile oils also evaporate in all temperatures. But sulphuric acids or oil of vitriol and fixed oils, never assume the form of vapour until heated to a certain degree. The following table shows the points at which various substances melt, boil, and congeal, according to the scales for measuring heat of Wedgewood and Fahrenheit.

Table of the effects of heat on various substances, measured in the higher degrees of temperature, by Wedgewood's pyrometer, and in the lower temperatures by Fahrenheit's thermometer. Wedgewood's scale begins at red-heat visible in day-light, corresponding to 1077 degrees of Fahrenheit, and rises to 240 degrees. The parts or degrees on these two scales are extremely different in magnitude. According to Wedgewood, water freezes at—8.142, and boils at—6.658, both below Zero or the beginning of his scale; making the difference between the freezing and the boiling points of water 1.484 degrees, whereas according to F. water freezes at 32 degrees, and boils at 212 degrees, making the difference between the freezing and boiling points 180 degrees.

Wedgewood.			
Wedgewood's greatest heat	240	Steel turns deep blue . .	580
Nankeen Porcelain stands .	160	Oil of Turpentine boils	560 / 325
Best China ditto softened .	156	Lead melts	540
Pig Iron completely melted	150	Bismuth ditto	460
Bristol Porcelain stands .	135	Steel Straw coloured . .	460
Pig Iron begins to melt .	130	Lead four, Tin one, melt .	460
Smith's Forge	125	Tin melts	408
Plate Glass furnace . . .	124	Bismuth one, Tin one, melt	283
Inferior China softens . .	120	Nitric Acid boils	242
Flint Glass furnace . . .	114	Solution of Salt ditto . .	218
Derby Porcelain vitrifies .	112	Water boils, when the barometer is at 30 .	212
Chelsea ditto ditto .	105	A mixture of Bismuth 8, Lead 5, and Tin 3, melts	210
Stone Ware baked . . .	102	Alcohol (pure spirit) boils	174
Welding heat of Iron . .	95	Bees-wax melts	142
Worcester Porcelain vitrifies	94	Heat of Tea and Coffee	115 / 130
Welding of Iron begins . .	90	Feverish heat . . .	112 / 107
Working heat of Plate-glass	57	Hatching Heat	108
Delft-ware baked . . .	41	Pleasant Bath . . .	106 / 92
Fine Gold melts	32	Blood Heat	100 / 96
Fine Silver melts	28	Temperate air	62
Swedish Copper ditto . .	27	Ice melts or Water freezes	32
Brass ditto	21	Milk freezes	30
Enamel burnt on	6	Sea-water ditto	28
Red-heat visible by day .	0	Wine ditto	20
Fahrenheit.		Alcohol 1, Water 3, ditto .	7
Red-heat visible in the dark	947	Do. 1, do. 1, do. below 0 .	— 7
Antimony melts . : . .	809	Do. 2, do. 1, do.	—11
Zinc ditto	699	Mercury do. contracting about $\frac{1}{21}$ part . .	—39
Mercury boils . . , .	660 / 655		
Expressed Oils boil . .	600		
Sulphuric Acid boils .	590 / 546		

When visible vapour has been deposited from transparent air, from cold or any other cause, it generally remains suspended for some time, in the form of mist or cloud. At some times, however, it is at once deposited on the surface of a solid body in the form of *dew* or *hoar-frost*. The dew seen on vegetables is partly derived in the evening from vapours ascending from the heated earth, since it is found on the inner surface of garden bell-glasses; and in the morning from the moisture descending from the air above, as it begins to cool. At other times however the dew, in warm weather, begins to fall in the evening. So plentifully does this evening dew fall immediately after sun-set in hot weather in Spain, Italy, and the south of France, that the people of those countries carefully avoid going abroad, to enjoy the cool of the evening, until the dew be all deposited. It is there called *serena* or *serein*, on account of the calm serenity which usually pre-

vails at that time of the day. Dew is probably only a portion of the vapour formerly suspended in the air, but condensed by the cold of the evening. It is remarkable that out of a number of bodies exposed to dew some are quite wetted by it, while others remain dry: thus metals remain dry, when glass near them is quite wet. This may perhaps depend on the circumstance that metals being good conductors of heat, readily part with it, to produce speedy evaporation, while glass being a bad conductor of heat, retains it and produces only a very slow evaporation or drying. The truth of this observation is however not confirmed in the case of every good conductor.

Mists are said to consist sometimes of other particles besides pure water: these are called dry mists, and have been supposed to blight vegetables. Such mists are sometimes attended by a smell resembling that produced by a spark of electricity. Rain falling after a dry season deposits particles of various foreign matter, brought down with it from the atmosphere. The difference between the rain collected in the heat of a large smoky town, and that collected in the open clear country, is two notorious to require description. The inconceivably fine farina or flour of plants, has been carried by the wind thirty or forty miles from the spot where it was produced. Sir William Hamilton, British ambassador at Naples, relates that thick clouds of extremely minute volcanic ashes overshadowed Taranto (*Tarentum*,) and the whole province of Lecce, extending sixty miles farther in the same direction, on the 18th of June 1794, which had proceeded from mount Vesuvius near Naples, during the very awful eruption of that volcano in the morning of the 16th of the same month. The distance from Vesuvius in a straight line across Italy east to Taranto, is 160 English miles; and the far point of Lecce is nearly 220 miles from the volcano. In the same manner may the minute eggs or animalcules, producing insects injurious to vegetation, be transported from the continent across the sea to this country, by a strong easterly gale, and afterwards deposited on our trees, hedges, fields and gardens, by their own weight, or by adhering to the particles of mist and fog. The fog in this case is blamed, not for its own misconduct, but because it introduces very noxious strangers.

When the light vesicular globes forming vapour or a cloud are, either from their mutual attraction, or the increased action of cold, still more condensed, and become even solid, they are too heavy to be supported in the atmosphere, and fall to the earth in the form of *rain*. In their descent several of these drops unite together, so that when they arrive at the ground they are much larger than when they first begin to fall. Another fact respecting rain, well ascertained by experiment, is this, that not only larger drops, but a greater quantity of water falls on the ground than originally proceeded from the cloud. Hence it appears, that the drops of rain, in their descent, not only often unite together, but also attract additional moisture from the different strata of inferior air, as they fall through them.

When a cloud or vapour is exposed to a current of cold air, of a certain temperature, its particles are congealed or crystallised in a loose separate form. Portions of the cloud in this state are, by their gravity detached from the rest, and descend to the ground in light fleecy flakes of *snow*. If however, the cold acting upon the cloud has been only sufficient to condense it into globules of rain, and that these

globules shall, during their descent pass through a stratum of very cold air, they will be completely frozen, and come to the ground as *hail,* and even (when a multitude of drops are suddenly condensed into large solid masses,) as solid pieces of *ice.*

Explanation of the air-pump in Plate II. Fig. 2. At A A are two brass barrels, each containing a piston with a valve opening upwards, worked by the handle B, having a pinion that works in the teeth of the racks C C. On the wooden frame E D, is a brass plate G, and also a brass tube communicating with the barrels and the cock I. The glass vessel K has its rim ground perfectly flat, and rubbed with hog's lard to make it exactly fit the plate G; this vessel is called the receiver, and from it the air is extracted by the action of the pistons, when the cock I is shut, by which alone it could gain admittance.

SECT. IV.

ACOUSTICS.

The transition from Pneumatics to Acoustics is quite natural; for the latter, as the Greek term signifies, instructs us in the nature of *hearing* and *sounds,* which are usually conveyed to us by means of the air around us. In the early days of natural knowledge, sounds were supposed to have a real separate existence, like the odorous particles of various substances, and that hearing was excited by the action of the particles of sound upon the ear, in the same way as smelling is excited by the action of odoriferous particles upon the nostrils. The Greek philosopher *Zeno,* however, three centuries before our Saviour, taught that hearing was produced by the air situated between the sounding body and the ear. "The air," said he, "is agitated in every "direction, from the sounding body, and moves from it in waves "which fall upon the ear, in the same manner with the circles pro-"duced in water, by a stone thrown into it." This opinion admirably simple and intelligible, has been confirmed and illustrated by the experience of the greatest philosophers, down to the present day. Thus a bell rung under water, gives a sound as distinct as in the open air: and it has been ascertained, that fish have a strong perception of sound, even at the bottom of a deep river; tame carp in the bottom of a pond will rise upon a call or whistle. The production of circular waves in a pond by the impression of a falling stone is an experiment obvious to every eye. In sound we cannot render the operation an object of sight; but when similar effects are produced, we are warranted to suppose the existence of similar causes. A stone slipped gently into water will create no circulating waves; in the same way an impression made gently on the air will excite no sound; but if the impression be sudden and forcible, waves of air will be produced which extending in all directions will excite the sensation of hearing on every ear within the bounds of those circles, the more or less powerfully, as the ear is less or more remote from the centre. The sense of hearing is occasioned by the undulating or waving motion of the air, col-

lected by the funnel of the outward ear, and conveyed through the auditory passage to a very thin transparent membrane, stretched over the inner end of the passage, like the parchment over the head of a drum. From this circumstance it is called the *tympanum* or drum of the ear. The waves of air collected by the funnel of the ear, in greater quantity than would fall upon the drum itself if exposed to them, press upon that membrane which, by its motion, acts upon nerves communicating with the brain, when immediately the sense of sound, or hearing, is excited. If from any cause, the air be prevented from reaching the tympanum, or if that membrane be rendered inflexible, so that the motion of the air shall produce no motion in it, or that the internal parts of the organ have lost their activity; in all these cases no impression will be made on the brain, no sound will be perceived, and the person is said to be deaf. It was before said, that a bell rung in water communicates its motion to the water, which does the same to the air upon its surface, and the sound of the bell is heard just as distinctly as if it had been rung in the open air. Again, if a bell be rung in a vessel, from which the air has been exhausted by the air-pump, no sound will be produced: but if it be rung in a vessel into which a greater quantity of air than is naturally the case has been forced, the sound of the bell will be proportionally increased. The progress of the circles of water made by the stone may be measured; but the circles of air travel much faster. By experiment it is found, that sound moves at the rate of 1142 English feet in one second of time, or very nearly 13 English miles in one minute, or 778 miles in one hour. That sound is not produced instantaneously but moves in a certain rate, is obvious to every man's observation. We see a man felling a tree at some distance: we see the fall of the hatchet, but it is again raised in the air to repeat the stroke, before the sound of the first come to our ear. We see the smoke from the fowling-piece across a dozen of fields; but a sensible interval takes place before the report affect our hearing. By the rate of the motion of sound we are enabled to compute the distances of objects. Thus a ship out at sea in the night fires a gun as a signal of distress. The flash is observed by persons on shore, who remark that the report does not reach their ears till just seven seconds after the flash. Multiplying by 7 the number of feet travelled by sound in 1 second, viz. 1142, we have 7994 feet, equal to $1\frac{1}{2}$ mile and 296 feet: this therefore is the distance of the ship from the observers at the firing of the gun. By the same rule we may estimate the distance of a thunder-cloud, if we carefully notice the time elapsed between the flash and the report. Hence we may draw an argument to remove the terror absurdly felt by many persons at the rolling report of the thunder, although the flash of lightning, by which the report was produced in the air, was beheld with little concern. The motion of lightning being incomparably swifter than that of sound, no person who heard the report, could possibly be affected by the flash or discharge. The motion of sound is here given at 1142 feet in one second; but some late observers are inclined, and on good grounds, to diminish that velocity, and to estimate its motion at only 1130 feet in a second.

Sounds of all kinds travel equally quick: the report of a gun and the stroke of a hammer; the loudest thunder and the lowest whisper, (as far as it is heard) move all with equal velocity. Smooth and clear

sounds proceed from bodies all of one substance and of an uniform figure: harsh sounds proceed from bodies of a mixed nature and an irregular figure. All substances are, in some measure, conductors of sound. If you stop one ear, and to the other apply the end of a long rod of timber, at the opposite end of which a watch is applied, the beating of the watch will be distinctly heard through the rod. The same effect will be produced if you stop both ears, and take the end of the rod between the teeth. A gentle scratch made on the end of a long deal plank will be plainly heard, if the ear be applied to the other end, although in the open air it would be quite imperceptible. If between the legs of a pair of tongs you pass a garter or a piece of flannel, and pressing the ends of the garter, by a finger of each hand, into the ears, then raise the tongs from the ground, while another person strikes on the legs of the tongs with a key, the vibratory motion thus excited in the tongs, communicated immediately to the ears, will produce a sensation like the loud ringing of a large church-bell. The earth is also a good conductor of sound: advanced parties of an army, highwaymen, &c. have been warned of the approach of horses, by applying an ear to the ground.

The Echo. When a stone is thrown into a pond, it raises up circles spreading in all directions. If before the impression decay, the waves strike against the margin of the pond, a wall, or any other obstacle, a fresh impulse is given to the water, but in a contrary direction; and the two sets of waves are seen meeting and crossing each other. Just in the same way if sound strike against a wall, the face of a rock, or any other unyielding substance, its waves are turned backwards, and a second sound is produced, at an interval from the first, proportioned to the distance of the original sounding body from the reflecting body. This is called an *echo*, a Greek name, meaning however merely a sound. It is on the principle of the echo that we account for the prodigious noise excited in a large empty hall, with regular smooth walls. Let one play on the violin in such a space, and the sound will be equal to that produced by a number of such instruments in a common room. But if the instrument be carried into a bed-chamber, with a carpet, window-curtains and hangings let down, these substances being unelastic, do not reflect the sound, and the violin will seem to have lost the best part of its powers. Supposing a room to be constructed in the form of an ellipse or oval, a sound proceeding from a person placed in one focus will be reflected to, and distinctly heard by one standing in the other focus, and distinctly heard no where else. The same effect is produced likewise in circular domes, as in the *whispering-gallery* of St. Paul's church in London, where a whisper uttered against the wall, at one side of the dome, is reflected to the opposite side, and there distinctly heard. Hence we see the principle on which are constructed the speaking and the hearing trumpet. When we speak in the open air, the effect on the ear of a distant hearer is produced by only one impulse of the air, moving straight forward: but when we speak through a tube, all the pulses propagated from the mouth, excepting those in the direction of the tube, must strike against its sides, from which being reflected, a great number of impressions must necessarily be reflected to the ear at a distance. Hence it follows that by using a tube or trumpet many more waves of air may be made to strike the ear than without it, and consequently the person at a distance may

hear the voice and words as distinctly, as if he had stood near one speaking with the mouth alone. The hearing trumpet acts in a similar manner, but reversed. In the open air only a few direct impulses of air can touch the ear; and if the membrane be rigid or its sensibility weakened, sounds will be but very feebly, if at all perceived. But the wide open mouth of the trumpet collects a great body of impulses, which being carried forward by repeated reflection from the sides of the instrument, as it contracts in diameter, are at last brought to act so forcibly on the organ of hearing that a sound may now be audible, which, without this aid, would be entirely inaudible. The human voice acts by impressions made on the air by organs in the upper part of the throat: and by the application of the tongue, palate, teeth, lips, &c. the sounds thus produced are subjected to an infinite number of modifications, according to the practice of different nations, by which the members of the society are enabled to carry on a mutual interchange of sentiments. The sounds of a violin, a harp, or any other stringed instrument, are equally produced by the rapid impulses communicated to the air by the strings, either when touched with the finger or acted upon by the roughened hairs of the bow; and as a string makes all its vibrations in the same time, whether they be great or small, the effect in moving the air must be the same, and consequently the sound or note or tone must always be the same, whether the string be touched soft or strong.

SECT. V.

OPTICS.

The science of optics, that is of sight or vision, is founded on the nature and properties of light, and consists of two principal branches. 1st. *Catoptrics,* from the Greek *catoptron,* a speculum or mirror; relative to light reflected from polished or smooth surfaces. 2d. *Dioptrics* from *dioptesthai* to see through; relative to the refraction produced on light in its passage through different media or substances, as air, water, glass, &c.

Light, if it could be defined, is too well known to require any definition. It is by the light of the sun, or by that which proceeds from burning bodies, that we have information of the position and presence of external objects at a distance; or the rays of light proceeding from those bodies, and entering our eyes, produce the sensation of vision. Of the nature of light we have no certain notion; but two principal opinions have divided the learned. The first is that of *Des Cartes* of France, of *Huygens* of Holland, and of other eminent philosophers, who conceived universal space to be filled up with a very fine and subtile fluid, which is agitated or put in motion by the sun and burning bodies. This motion consists of vibrations, and undulations, or waves, which extending themselves in all

directions, and reaching the eye, render visible the objects from which these motions are produced. The second theory is proposed by the illustrious *Newton* and his disciples. According to this theory, light is a real material substance, emanating or proceeding from luminous bodies. It is a subtile fluid, composed of peculiar particles of matter, constantly separating from luminous bodies, which entering the eye excite the sensation of light and of sight, or the perception of the objects from which it originally proceeds, from which it is reflected, or through which it is refracted. This theory deduced from a great number of facts and observations, was established by Newton upon mathematical evidence and demonstration. If then it be admitted that light is a subtile fluid substance, consisting of minute particles, we are naturally led to consider their most obvious properties, such as their velocity, their magnitude, their force, &c. One of the most astonishing properties of light is the velocity with which it moves. The mean distance of our earth from the sun is 95 millions of English miles: that of Jupiter in the midst of his moons is 490 millions. When therefore he and we are both in a line on the same side of the sun, we are nearest together, and 395 millions of miles (the difference between 95 and 490) is the distance between us. Again, when Jupiter and we are directly opposite to one another, on different sides of the sun, the distance between us must be the greatest, or 585 millions of miles (95 and 490): the difference therefore between our greatest and our least distance from Jupiter is 190 millions of miles. Now an eminent astronomer of Denmark, *Roemer*, observing the eclipses and other appearances of Jupiter's moons or satellites to happen about eight minutes and thirteen seconds sooner than the time calculated, when the earth was between him and the sun; and about eight minutes later than the time calculated, when she was on the opposite side of the sun; making a difference in time of sixteen minutes and a half; he very sagaciously conjectured and proved that this difference could be produced by nothing but the time necessary for the progress of light from Jupiter to the earth, in the opposite points of her course round the sun. The difference between the distances of the earth and Jupiter was shown to be 190 millions of miles; but the sun being only one half of that difference in distance from us, it follows that light travels to us from the sun 95 millions of miles in eight minutes and one-fourth, or about the rate of nearly 200 thousand English miles in one second of time; a velocity of which the human mind can form no distinct conception. A cannon ball is computed to fly at the rate of eight miles in one minute, that is, 64 miles in eight minutes and one-fourth, while light travels 95 millions of miles; light must therefore move with a rapidity towards a million and a half times faster than a cannon ball, which would at its ordinary rate employ above 22 years and a half in passing between the earth and the sun.

From the inconceivable rapidity of light may be inferred the extreme minuteness of its particles. The force with which moving bodies strike others at rest, is in proportion to their mass, or the quantity of matter they contain, multiplied by their velocity: a swift blow with a light hammer will drive a nail into the wood, when a very heavy load merely resting on it would have very little effect. With the prodigious velocity of light, unless its particles be inconceivably minute, its effects upon the bodies exposed to it would be most destructive. Indeed were the

particles of light even of such a bulk, that two millions of them would only be equal to a grain of common sand, their impulse would not be less than that of sand shot from the mouth of a cannon. The minuteness of the particles of light may also be shown from the great facility with which they penetrate and pass through transparent but solid bodies. In passing through such bodies light seems not to suffer the smallest diminution of its velocity. If there be nothing to obstruct the rays of light proceeding from a candle, it will fill the whole space, within two miles round, almost instantaneously, before it has lost the smallest sensible part of its substance.

The particles of light move with equal freedom in all directions from the luminious body, without the least apparent jostling or disturbance. If in a sheet of paper you make a small pin-hole and look through it, you will see a number of objects, much as if no paper stood in the way; which can only be occasioned by the rays of light proceeding in all directions from those objects. By a *ray of light* is meant one of its particles in motion; which is always performed in straight lines: hence it is impossible to see through a crooked tube.

As these rays spread out in all directions from their central point in the luminous body, it follows that a much greater number of them will fall within any given space, as a sheet of paper, when placed near the centre than when removed from it. The number of rays, or the strength and intensity of light on the paper will decrease in the regular proportion of the square of the increasing distance from the luminous body. If it be removed to twice its distance, it will receive but one-fourth part of the former light; if to three times that distance, the illumination will be reduced to one-ninth part, and so on. Whatever be the light thrown on a sheet of paper, a book, &c. from one candle at the distance of one yard, it will be reduced to one-fourth at the distance of two yards, to one-ninth at three yards, to one-sixteenth at four yards, &c. Or at four yards sixteen candles will be required, at three yards nine candles, and at two yards four candles, to throw the same quantity of light upon the paper, as was done by one candle of the same sort at the distance of one yard. As the same diminution of light and heat proceeding from the sun must take place in all the planets revolving round him, in proportion to their relative distances, we may compute the quantity enjoyed by each, making that which we enjoy the standard or unity. The earth is twice and a half as far from the sun as Mercury is, and the square of 2.5 is 6.25: he therefore enjoys six one-fourth times as much light and heat as we do. Venus being two-thirds only of our distance from the sun, receives two one-fourth times our light. Mars is one and a half time of our distance: he consequently receives less than one-half of our light. Jupiter is distant from the sun full five times our distance: he therefore possesses only one-twenty-fifth part of our light. Saturn is distant nine and a half times, and consequently his benefits from the sun must be only one-ninetieth part of ours. And the far-distant Herschel, twice as remote at Saturn, and nineteen times farther from the centre of light and heat than we are, can enjoy but one-three hundred and sixtieth portion of what we receive. The inhabitants of each of these globes are nevertheless wisely adapted by their Creator, to the circumstances in which they are placed.

In speaking of optics sundry terms must be employed, of which the

following are the chief:—A *ray* of light, as was first said, is a particle in motion, always performed and represented as a straight line. A number of rays proceeding together from any point, and considered in their conjunct state, is called a *pencil* of rays, resembling the hairs in a drawing pencil. A *medium* (a middle or intervening substance) signifies a body of such a nature as to suffer rays of light to pass through it. Such are air, water, glass, &c. which are therefore said to be diaphanous, pellucid, or transparent, the first a Greek and the others Latin terms, expressing that which may be shined through, or through which objects may be seen. Rays that move always at equal distances are said to be *parallel*; but if they continually recede from one another, like the radii of a circle from the centre to the circumference, they are said to *diverge* (to be separated). On the other hand, rays tending to a meeting, or from the circumference of a circle to its centre, are said to *converge* (to be drawn together): and the point at which they meet is called the *focus* (fire-place). When rays, after passing through one substance or medium enter another, and are then bent out of their first direction, they are *refracted* (bent back): when they strike against a surface and are thrown back like a marble from the pavement, they are *reflected* (bent forward). If the marble fall from the hand perpendicularly upon a horizontal pavement, it is thrown up again in the same perpendicular direction: but if it be made to strike the stone with an oblique inclination, it will fly off in the opposite direction, making with the pavement an angle precisely equal to that with which it struck it. A *mirror* or *speculum* is an opaque (that is, not transparent) body, of which the surface is very smooth and finely polished, so as to reflect the rays of light that fall upon it, and thereby to exhibit images or representations of objects before it. Mirrors are generally made of metal or glass polished and silvered: those of metal consist of copper with a small proportion of grain tin; and in some a little silver, brass, and arsenic are intermixed. Glass mirrors are silvered in this way.—Upon a large slab of marble, well polished and ground, perfectly true and even in every direction, a quantity of tin foil (tin hammered into a thin leaf) is spread and pressed down quite smooth. On the foil a little mercury (in which some tin has been dissolved) is dropped, and with cotton or a hare's foot, is spread all over the foil, until every part be touched by the mercury, which incorporates with it, forming what is called an amalgam. The plate of glass is then applied to the side of the slab or table, and cautiously slipped over the surface of the tin and mercury. Weights are then laid on the glass, to press out the redundant mercury, and to promote the adhesion of the amalgam with the under surface. When this is done the silvering is finished, and the mirror no longer transmits but reflects the rays of light. Mirrors are either plain, convex, or concave. *Plain*, or better *plane*, mirrors have their surfaces perfectly even and in straight lines in all directions: such are common looking-glasses, a term which, by the by, is no more than a translation of the French *miroir*. *Convex* mirrors have their middle parts more prominent than the edges. Those most generally used may be considered as a portion cut off from a glass globe, the swelling outside of which is turned to the light or the eye. *Concave* mirrors, on the contrary, are the inside of the section of a hollow glass globe. These two kinds of mirrors may, however, be sections of all

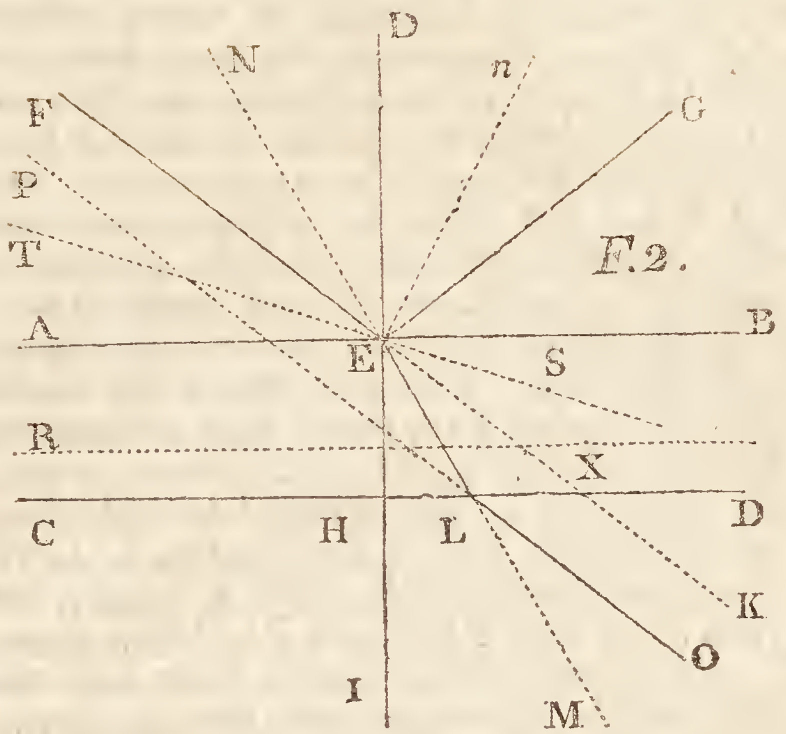
other regular curved bodies, as well as of globes; such as of a cylinder, &c. which afford much entertainment by their power of distorting the images of men or other objects brought before them.

A *lens* is a circular piece of glass, ground into various forms, by which it is made to collect or disperse the rays of light that fall upon and pass through it. The original and proper lens is thin all round the edge, and swells out regularly, in the arch of a circle, on both sides to the middle. Such are spectacle, reading, magnifying, and telescope-glasses; and from this shape they draw their name: for such is the form of the vetch, called in Latin *lens*. When a lens is thus swelled out on both sides like a vetch, it is called a *double convex* glass. When one side only is swelled out, and the other is straight and even, it becomes *plano-convex*: when one side is hollowed out, and the other straight, it is *plano-concave*; and when both sides are hollow, it is a *double concave*. If one side be concave and the other convex (not however arches of concentric circles, so that the glass is every where of the same thickness) but thicker in the middle than at the edge, the lens then becomes a *meniscus*. This term signifies in the Greek a little moon, or something moon-shaped; and of a lens of this shape we have a perfect image in the appearance of the moon, three or four days after or before her change. The common watch-glass, thicker in the middle than at the edge, is a meniscus. A line passing through the centre of a lens, at right angles to its plane, is called its axis. Any solid figure consisting of three equal sides, each being a parallelogram, and its two ends equilateral triangles, is a regular *prism*. Such a figure composed of crystal or pure glass is of constant use in illustrating the nature and properties of light, and known by that name.

Reflection and Refraction. It was already said that, when rays of light strike against an opaque or non-transparent substance, they are thrown forward, *reflected*, like a marble rebounding from the pavement. On the other hand, when rays pass out of one substance or medium into another, of a different degree of density, whether rarer or denser, they are as it were broken backward or *refracted*.

It is however to be observed, that the whole of a ray of light is never reflected from any surface, a small part penetrating, and, in some cases, passing through the reflecting body. In the same way the whole of a ray, falling obliquely on a transparent medium, is never refracted, but a small part is reflected from the surface on which it falls. But in the observations which follow on reflection and refraction, this nice distinction is not taken into consideration.

The angle formed by the ray and the nearest part of the surface is called the angle of *incidence*, and that formed between the farthest part of the surface and the ray when flying off is the angle of *reflection*; and these two angles are always equal the one to the other. The angle of *refraction* is that formed between a refracted ray and the perpendicular.



Of these observations a competent notion may be formed, by a reference to the preceding diagram. Let A B Fig. 2. represent the upper, and C D the under surface of a medium of any kind, as in the first place a smooth polished slab of marble, If from D, over the middle of the slab lying perfectly horizontally, I drop a marble, it will fall in the perpendicular D E, and strike the slab at E. From the elasticity of both bodies, the ball will be thrown back or reflected, precisely in the line of its fall, from E towards D; and if suffered it will continue for some time to fall to E, and bound up towards D, shortening every time the height of the bound, from the constant action of gravity, and will at last remain unmoved upon the slab at E. Let the marble now be taken up to F, and thrown so as to strike the surface of the slab at E; it will rebound but not in the direction of its fall back to F, nor up as before to D, but in the direction E G, which is inclined to the surface A B, at an angle precisely equal to that of the direction F E. That is the two angles G E B and, F E A are equal. But G E B is the angle of reflection, and F E A is the angle of incidence; these two angles are therefore always equal. The same consequence will follow if the marble strike and be reflected from the surface in the directions of N E and E *n*, for the angles N E A, and *n* E B are also equal. The angles D E A, and D E B, being formed by a perpendicular, must be both right angles and consequently equal. Now what is here spoken of a ball, and a slab of marble, is correctly true of the impulse of all other elastic bodies, (and what material substance is not elastic?) and consequently of a particle of light.

Let us next suppose, A B and C D to be the upper and under surfaces of some medium much denser than common air, and that these surfaces are truly parallel. If a particle or a continued succession of particles forming a ray of light fall from D through the air perpendicularly upon A B at E, it will preserve its direction, pass directly through the water (for we here take no notice of the vessel containing it, which besides may be of transparent glass,) and again enter the air at H, from which point it will continue the same direction to I. On the

other hand, let a ray fall in any inclination as in F E; this ray we should expect to pass forward through the water in the same direction like E X K, but no; on the contrary the ray is bent down toward the perpendicular E H, so as to proceed through the water, in the direction of the line E L, as if it had gone straight along N E L; F E is therefore at E refracted into E L; and the ray, instead of leaving the water at X, leaves it at L. But water is a medium much more dense than air; it therefore appears, that a ray of light, proceeding from a rarer to a denser medium, is bent in or refracted nearer to the perpendicular passing through the denser medium, than was its former direction in passing through the rarer. This however is not all, for the reverse of this fact takes place when a ray passes from a denser into a rarer medium; the direction of the ray E L is therefore, upon passing out of the water into the air at L, less attracted towards the perpendicular E H I, and turns off from L M in the direction L O, which is always parallel to its original direction F E, while in the air, before it entered the water. The whole lines F E K, and P L O are always parallel; consequently in passing from a denser into a rarer medium a ray of light is less refracted towards, or diverges more from the perpendicular, than while in the denser substance. Nor is this effect confined to rays falling from a rarer medium into one more dense placed below it; for the ray O L proceeding upwards through the denser medium above it, will be equally refracted nearer to the perpendicular as in L E; and on entering the air above the water will again fall away from the perpendicular, as E F. Whatever be the position of the dense medium, A B D C, with relation to the rare medium on each side, the effects are constantly the same. The ray F E being refracted at E from its original direction E K into E L M, H E L, or I E M, becomes the angle of refraction.

It is a maxim in optics, that we perceive objects only in the direction in which the rays of light come from them to our eye, without regard to the real direction in which the objects are situated with respect to us, If a mirror be so placed in one room, that by standing on one side and looking into it obliquely, I can perceive objects in the adjoining room of which the door is open, I can form a notion of those objects just as well as if, the intermediate wall being removed, I saw them by direct vision. Standing at F, (see preceding figure,) and looking to the mirror at E, I perceive an object at G, by reflection, although by the wall between D and E, no ray can pass directly from G to F. From long and continual habit we are never misled by appearances produced by reflection from a mirror or other similar surface; but the effects of refraction occur very rarely, nor have we always the means of correcting the impressions they make on our senses and minds. The nature and cause of refraction are besides less obvious than those of reflection; although if this were the place for such an enquiry, it might not perhaps be difficult to show that both these effects on the rays of light are of a similar nature, and are produced by a similar cause.

That a ray of light is refracted in passing from a rarer into a denser medium, or the contrary, at the line where the two substances touch each other, may be seen by the following common experiment. Suppose E H to be the upright side of a vessel E H D B, containing only air. Let a ring, a shilling, or other small object be fixed with a little wax in the bottom of the vessel as at L, so that you can just discover it with the eye at N, over the edge of the side at E. Then step

backwards till the eye come to F, and the sight over E will strike the bottom of the vessel at X. Keeping the eye steady at F; let another person pour water gradually into the vessel, and as it rises, after some time the money, &c, will come into view, as at Q in the direction of F E; and if water be still poured in, the object will still appear to rise higher and higher, until the vessel be full; while the vessel contained only air, L was invisible from F, but when the water rose to a certain height the rays entering it from F E were bent downwards towards the direction of the perpendicular, from E Q X to E L, consequently L being seen over E by the eye at F, and we being accustomed to see objects either reflected as from a mirror, or in a direct line, we naturally conceive L to be seen in the straight line F E Q; and therefore conclude Q to be the true place of the object at L. But as the object was secured in the bottom of the vessel at L, which is now also in sight, we likewise conclude the bottom to be actually raised from the level of C L D to that of R Q, by which the depth of the vessel is apparently much diminished. If the vessel be filled quite up to the brim E B, the object L will rise above Q, and appear as at S, in the direction of S E T, but the observer at F will see S raised above the direction of F E, or in other words a ray of light passing by supposition through S E, and F, will appear to form an angle opening upwards at E, and instead of being straight will seem to be bent or broken upwards, at the surface of the water at E. That rays of light are refracted down toward the perpendicular, when they pass from air into water, will be evident from the following simple experiment. Exclude the light as much as possible from a room on which the sun shines bright, admitting only a small beam or ray through a hole made on purpose. In this ray place an empty bason, or other broad vessel, in such a way that the light may fall at the union of the opposite side with the bottom, and there make a mark. Now pour water gently into the vessel, and you will see the bright spot gradually moving away from its position, across the bottom towards the window, in proportion to the depth of the water poured in: an effect to be produced by no other cause than the bending down of the ray of light. If a little milk be dropped in the water, and some dust or hair powder be floating in the room, the experiment will be the more satisfactory.

Here we have an explanation of the common fact, that a stick or cane however straight, or an oar, laid obliquely in water, seems always to be bent or broken upwards at the surface. The cane N E L will be seen as N E Q; F E Q will be seen as F E S, &c. Hence also we ought to be careful in entering water that appears to be shallow; for a river or pond seemingly little more than four feet deep may upon trial be found in depth between five and six feet. From inattention to this fact, many alarming and even fatal accidents have befallen young persons in bathing; and it is to be particularly observed, that the purer and clearer the water, the more liable is the eye to be deceived, because there danger and deception are the least apprehended. But on the other hand, to the refraction of the rays of light, when passing from a rarer into a denser medium, we are indebted for many advantages daily and hourly enjoyed, but for which, from heedlessness, or because they are continually recurring, we seldom feel that gratitude which is so justly due to the beneficent providence by

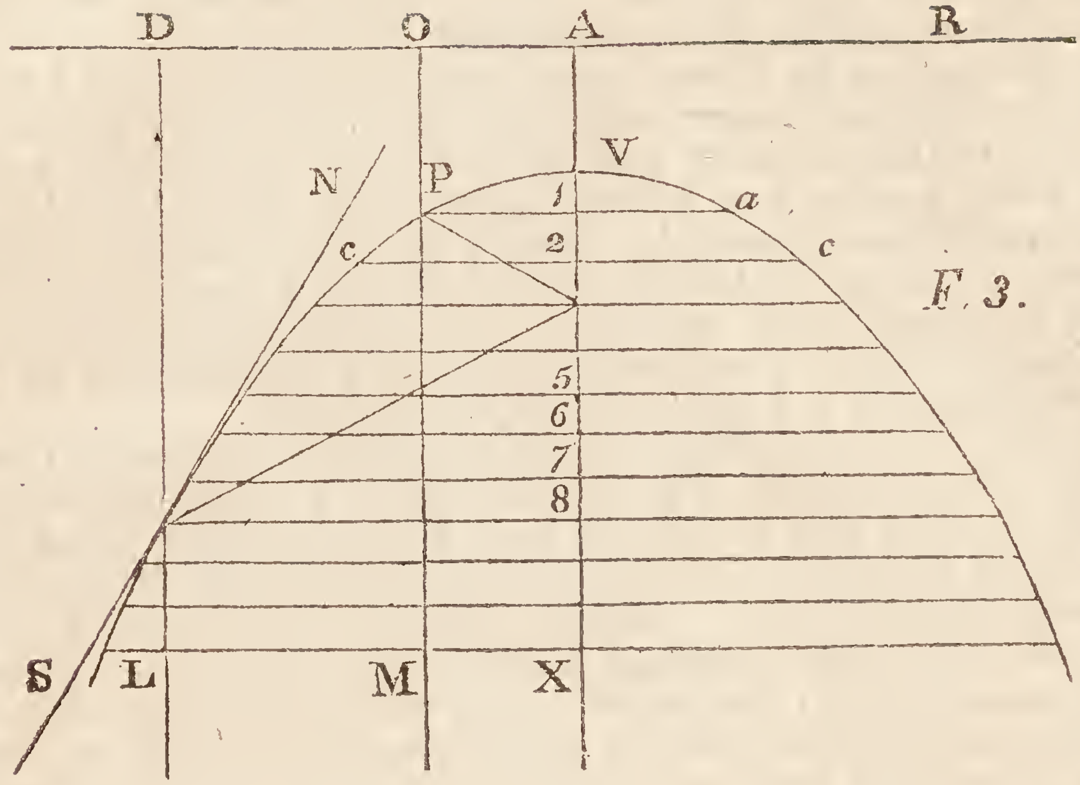
whom they are bestowed. We here allude to the effects of refraction on the rays of light proceeding from the sun, moon and other luminaries, in passing from the finer into the grosser parts of our atmosphere. By the diagram before given it was shewn that while air alone filled the vessel E H D B, an object at L was invisible by an eye at F: but that when water (a denser medium) was poured in, that object came into view at Q, and advanced even to S. Suppose now an observer placed at F on the surface of our globe, and that he look eastward along the horizon F E to the place where the sun is to rise, as at Q upon that line produced; were there no atmosphere, or were it not endowed with a refractive power, the sun would be quite invisible until he arrived in the direction of F E, as at Q. Our atmosphere however (as was noticed in speaking of pneumatics) being proportionally more dense, as it is nearer the earth, the sun's rays in passing through the different strata will be more and more bent down towards the surface; so that some time before he be actually arrived at Q, as for example's sake at L, his body will be seen by the observer at F. The sun will therefore appear to be risen above the horizon, and his light will actually arrive at F, when he is still actually at L. For the very same reason his light will continue, and his body will be seen, for some time after he is really set below the horizon in the west. At rising and setting his rays passing for the greatest distance through the densest strata of the atmosphere, there refraction is the most powerful; and in proportion to his elevation above the horizon, its effects are diminished, until he come to be directly perpendicular to the observer (which happens only within the tropics,) when all refraction ceases. From accurate computation and observation it has been found, that the refraction of light in the direction of the horizon amounts to thirty-three minutes of a degree, or that the sun or other luminary appears in the horizon, when it is really above half a degree below it; consequently that the luminary which ought to be visible only during its passage over a hemisphere or 180° is really to be seen for the space of 181° six minutes. Now as the sun apparently travels through 360° in 24 hours, and through 180 in 12 hours, owing to the refraction of our atmosphere, this period of 12 hours is enlarged to 12 hours 4 minutes 24 seconds of time. This effect of refraction may seem of little consequence in common life; in geography however and navigation, which chiefly depend for their certainty on the accuracy of astronomical observations, the change of place in celestial objects, occasioned by the rays of light passing through our atmosphere, comes to be of real importance, in ascertaining the latitude and longitude of a ship or a town. But independently of this real addition to our sunshine, and diminution of our night, to the refraction and reflection of our atmosphere we owe that intermediate portion of illumination called twilight, beginning when the sun is still 18° under the horizon in the morning, and lasting till he be as much under it in the evening. The general light perceived in a cloudless sky, and when there is no moon, is perhaps as much the effect of the sun's rays reflected and refracted from the more distant parts of our atmosphere, as of the stars and planets with which the heavens are bespangled. Were it not for these properties of the air we should be involved in merely star light until the very instant when the sun rose in full brilliancy above the horizon; and we should instantaneously pass from his greatest splendor into the same darkness, the moment his body

sunk under the horizon. He would shine upon us with meridian brilliancy while we looked at him: but the instant we turned our backs, we should see nothing but a midnight heavens.

In the diagram fig. 2. was shewn how any elastic body, as a ray of light, was reflected from a straight plane surface; a ray falling perpendicularly as D E, would be reflected in the same line as E D; another N E, would go off as E *n*, a third F E, would be reflected in E G, &c. Similar effects are produced by reflection from curved surfaces, whether concave or convex; because the point of the curve touched by the ray being indefinitely small, the curve and its tangent at that point may be conceived to coincide; and the tangent being a right line, the ray will be reflected just as if it had struck upon a flat surface.

It is not a little surprising, though it may seem invidious to remark it, that in the generality of treatises on optics, we find this assertion: "When parallel rays of light fall upon a concave mirror they will be "reflected, and meet in a point half way between the mirror and the "centre of its concavity." And this assertion is illustrated by a mirror the section of a sphere; although it must be obvious to every one but a little acquainted with the properties of parallel lines falling internally on the circumference of a circle, and consequently of a sphere, that if a radius be drawn from the centre to the point of the circumference, where any of those lines terminates, and on the opposite side of that radius a line be drawn from that point, forming with the radius an angle of reflection equal to the angle of incidence, such a line will, *in no possible case,* fall precisely in the middle point between the centre and the circumference of the mirror, upon the parallel ray passing through the centre of its concavity.

There is but one kind of concave surface, that will reflect all rays falling upon it, parallel to its axis, into one and the same point, with absolute geometrical accuracy; and that is the *parabolic.* If a cone be cut through in a plane or direction parallel to its inclined side, the curve bounding this section will be a *parabola.* This conic section or figure can be correctly drawn upon paper by a mechanical operation alone; but a number of points may be laid down by the compasses through which the curve may be drawn, with sufficient accuracy for the purpose of showing its several properties.



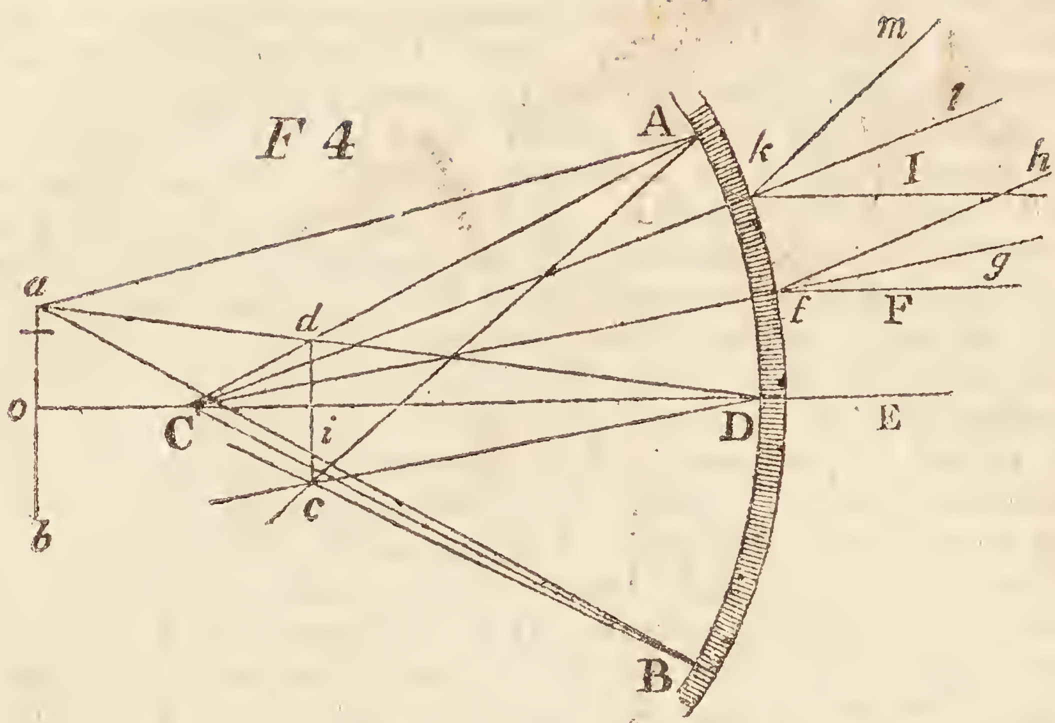
F. 3.

In the annexed diagram Fig. 3. D A R is the directrix of the parabola, because by it the drawing of the figure is guided. The perpendicular A X is the axis cutting the parabola into two equal parts: The point V is the vertex of the axis: all other perpendiculars to the directrix, such as O P M, D T L, are diameters. The point F, upon the axis, at a distance from the directrix at A, double that from V to A, is the focus of the parabola. It is a character of this curve, that if from any point in it, as from P, a line be drawn to the focus as P F, and another perpendicular to the directrix as P O, these two lines will always be equal. In the same way T F is equal to T D. Upon this property is founded the method of drawing a parabola by a number of points, in this way. On the middle of the directrix D R, draw the prependicular A X, on which set off A V and V F equal to each other, and of such a length as may suit the intended parabola, of which V will be the principal vertex, F the focus, and V F X the axis or principal diameter. Divide V X into a number of equal parts, the more and the smaller the more accurate will be the figure, as in the points 1, 2, &c. through which lines are to be drawn parallel to the directrix, and consequently at right angles to the axis; these lines are called ordinates. Placing one foot of the compasses in A and opening the other beyond V to 1 upon the axis, with that opening, from the focus F as a centre, make intersections at P and *a* on the ordinate passing through 1, when these two points will be in the curve of the parabola. Again with the distance from A to 2 in the compasses make marks at *c c* on the ordinate drawn through 2. In this way from the focus F, with the distance from A to any other point in the axis A X, make marks on the ordinate passing through that point, when those marks will be parts of the parabolic curve. That lines drawn from any point of a parabola to the focus and perpendicular to the directrix are equal, will be evident in this way. Take the point P, the extremity of the ordinate P 1 *a*: that point was fixed by intersecting a line through 1, parallel to the di-

rectrix, with an opening of the compasses set off from the focus F, equal to the space A 1: but A 1, and P O being parallel and connecting parallels, they must necessarily be equal: consequently P F being made equal to 1 A, it must also be equal to P O. In the same way T F is equal to T D; for it was set off from F with a distance equal to A 8, which is equal to T D. If the angle formed at any point of the parabola, by a perpendicular to the directrix, and a line to the focus, be divided into two equal parts by a line from that point; such a line will be a tangent to the parabola at that point, and if produced both ways will never fall within it. Thus the angle D T F is divided into two equal angles by T N drawn from the angular point T, and if produced in the opposite direction to S, will fall without the parabola. When two right lines intersect each other, the angles on each side are equal. L D intersecting S N in T, the angles L T S and D T N are equal: but D T N was made equal to N T F, consequently L T S must be equal to N T F. Suppose now L T to be a ray of light parallel to a centre ray X V, falling upon the concave parabolic surface at T: the tangent N T S may be considered as coinciding, for an indefinitely small space, at T with the curve; if therefore the ray L T strike the plane surface, N S at T, it will be reflected in T F in such a direction that F T N the angle of reflection will be equal to L T S the angle of incidence; the ray L T will therefore be reflected to F, the focus of the parabola. In the same way it may be shown that all other rays, parallel to the centre ray, X F V, will be reflected from the concave surface to the focus F. For if through the point P a line be drawn bisecting the angle O P F, that line would be a tangent to the parabola at P, and the ray M P would be reflected to F, making the angles of reflection and incidence equal. Hence it necessarily follows that rays of light, striking on the concavity of a parabolic mirror, in a direction parallel to the axis passing through the focus, will all be united after reflection in that focus: a fact that can happen in no other kind of curve whatever.

But notwithstanding all that has been said, it is to be observed that the small portion on each side of the principal vertex of the parabola, as P V *a*, contained in the greater mirror of a telescope, will so nearly coincide with the arch of a circle passing through these points, that their disagreement may be imperceptible to the best aided eye. This disagreement, however, as has been shown, is certainly real: and an error in the reflection of light being much more important than an equal error in its refraction, the effects of the disagreement between the circular and the parabolic arch of the great mirror must become of the greatest consequence: but to form a mirror or speculum of a true parabolic concavity is always a work of extreme difficulty.

F 4



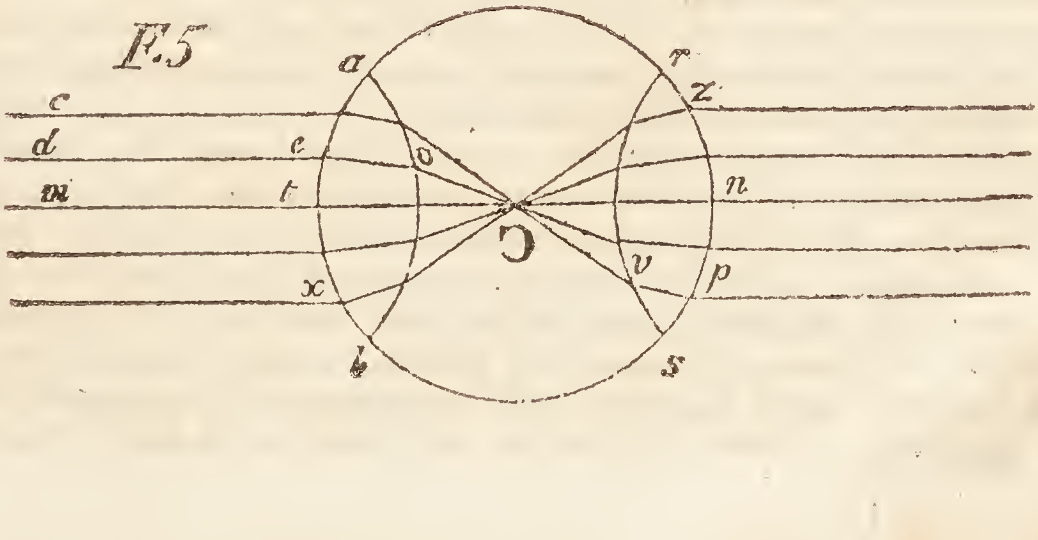
Let A B, fig. 4. be a concave spherical mirror, of which the centre is C, and D the termination of a ray passing through it. Let *a b* be any object placed before the mirror beyond the centre. The image of this figure will be seen between the centre and the mirror, as if suspended in the air and reversed as in the figure *c d*. Rays from every part of the side of *a b*, turned towards the mirror, will be alike reflected from every part of the concave surface; but here we confine ourselves to one point, viz. the extremity *a*. From *a* let three rays *a* A, *a* D, and *a* B, be drawn to the mirror, and from their extremities other lines be drawn to the centre C. Upon these last lines draw the lines of reflection A *c*, D *c*, and B *c*, meeting at *c*, which will therefore be the image of the point *a* of the object *a b*. In the same way, had rays been drawn to the mirror from the other end of the object *b*, they would, after reflection, have met in the point *d*; and the whole object *a b* would appear in the air reversed as in *c d*. The position of this image reflected from a spherical mirror, when the original object is beyond the centre of concavity, may in general be found by this position: as the distance between the object and the mirror, or *o* D, is to the radius of concavity C D, so is the distance of the object without the centre, or *o* C, to the distance of the image within the centre, or C *i*. When the object is on the outside of the centre of the mirror, the image within it is smaller than the object: when the original is between the centre and the mirror, as suppose *c d*, the image will be larger and beyond the centre as *a b*: when the object is placed in the centre of the concavity, the image is reflected back upon the original, and of the same size. Place yourself right before a concave spherical mirror, but farther off than its centre, and you will see your figure in the air, but upside down, and smaller than yourself. Hold out your hand towards the mirror, and the hand of the image will come out towards you; and when your hand is advanced to the centre of concavity, the other will coincide with it, of exactly the same bulk, so that you seem to shake hands with your own image. If your hand go on farther towards the mirror, the hand of the image will be seen between the centre and your body; if your hand be moved towards either side, the hand of the image will move to the

contrary. One curious particular of this is, that none of the bye-standers will perceive any part of the image, because none of the reflected rays will enter the eyes of any person, not standing in your precise position.

A ray of light falling perpendicularly upon a convex surface, as the outside of a globe, is reflected back in the same line; but every other ray parallel to it will be thrown off and dispersed with an angle of reflection equal to the angle of incidence, measured from the continuation of the radius of the sphere, and increasing in magnitude as the paralle rays are more and more remote from the perpendicular ray. Thus suppose E D in fig. 4, to be a ray falling perpendicularly, or in the produced direction of the radius D C, on the exterior convex surface of a mirror A D B, it will be reflected in D E; but the ray F *f* parallel to E D makes the angle F *f g* with the perpendicular or produced radius *f g*, and consequently flies off at an equal angle *g f h*. The next parallel ray I *h* forms with the perpendicular *k l* an angle of incidence I *k l* still greater than the former: it will therefore depart more widely in its reflection in the line *k m*, and so on.

Magnifying Glasses or Lenses. That rays of light in passing obliquely from one medium or substance into another, are refracted more or less towards the perpendicular to the second medium, according as that medium is denser or rarer than the first, was shown in explaining fig. 2. There however the observations were confined to substances of parallel plane surfaces; but when the media have spherical or other curved surfaces, the effects of refraction are peculiar and most important.—Parallel rays falling upon a plano-convex lens, will be so refracted as to converge and unite in a point behind the plane side, which is the principal focus of the lens; and its distance from the convex surface is always equal to the diameter of a sphere of which that surface is a portion. But when parallel rays fall upon a lens convex on both sides, they will be refracted into a point behind it, which is the centre of the same sphere. This is the case when the convexity of both sides is equal: when the two sides are portions of different spheres, the distance of the focus is found by combining the radii of both in this way: as the sum of the radii of both convexities is to the radius of one of them, so is double the radius of the other to the distance of the focus. Since all the rays of the sun which pass through a convex glass, are collected together in its focus, there must also be assembled all their heat, in proportion to the common heat of the sun, as the surface of the glass is to that of the focus; hence the power of burning-glasses.

F.5



Let $a\,e\,x\,b\,o$, fig. 5. be a section of a lens, equally convex on both sides, that is, the arch $a\,e\,x\,b$ is equal to the arch $a\,o\,b$. Let a ray of light through m fall exactly on the middle of the lens; it will pass directly through the centre of the lens, and be afterwards continued in the same direction without inflection or refraction of any kind, as m C n. Parallel to this centre ray let another pass through d and enter the lens at e. This ray, as will be seen by a reference to fig. 4, will fall obliquely on the circular surface of the lens, and be refracted as in $e\,o$, in a direction pointing to n, the extremity of the diameter of the circle $a\ r\ n\ s\ b$, of which the convexity of the lens is a portion. But when the ray comes out of the opposite surface at o, which is of the same convexity, it will be again refracted to C, the centre of that circle, that is, to a point at half the distance of n, to which the refraction $e\,o$ was directed. After its arrival at C, the ray $d\,e$ will proceed in the direction of o C, without any other inflection. What here happens to this ray will happen to every other ray parallel to m C: but their positions will be inverted. The upper ray c will after refraction through C become the lower ray, and the lower ray x will become the upper ray beyond C. Consequently rays falling upon a lens of equal convexities will be refracted towards a continuation of the centre ray, and will all meet in it, in the centre of the circle of which the external convexity of the lens is a portion. At that centre, which is the focus of the lens, the position of the several rays will be inverted, and they will all diverge in the directions in which they met. But suppose now another lens, of exactly the same convexities with the former, to be placed equally distant from C, and that the ray m C shall pass through its centre to n, then all the rays diverging from C, will enter the internal convexity of the lens, be refracted toward the centre ray n, and again on coming out of the glass into the air, be refracted still more, and then be continued parallel to the centre ray (although in an inverted order) as they were originally before they entered the first lens. For example, the ray $d\,e$ being refracted down into $e\,o$, and again into o C, will enter the second lens at v, there be refracted up into $v\,p$, in a direction pointing to the end of the diameter t, just as $e\,o$ was directed to the other end n, and on leaving the lens at p, be again refracted into a direction parallel to the centre ray $m\,t$ C n. If a candle be placed at C, the focus of the lens $a\,o\,b$, the light after passing through it, will proceed in parallel rays: but if the flame be placed between C and the lens, the rays will diverge; and if it be placed farther from the lens than C, the rays will converge, and meet at a point more or less distant from the glass, as the candle is nearer to or farther from the focus C: and where they meet they will form an image of the candle reversed, with the flame downward. The truth of this may be seen by receiving on a piece of paper the image of a candle passing through a common reading or even good spectacle-glass.

The effect of concentring the rays of light and heat from the sun, by means of a lens, are much more powerful than will easily be believed. Burning-glasses appear to have been known to some of the ancients. Diodorus Siculus, and other late historians, affirm that, above two hundred years before our Saviour, the great geometrician *Archimedes*, by means of glasses or other mirrors, set fire to the Roman ships of war employed in the siege of Syracuse in Sicily. This apparatus, however, if there be any truth in the story, was more

probably composed of reflecting mirrors than of transparent lenses.—That the use of lenses was really known in Greece long before that time, is plain from a passage in the famous comedy of the *Clouds*, in which Socrates, then living, is ridiculed. Of the modern burning-lenses the most powerful by far is that constructed for the late celebrated Dr. *Priestley*, by Mr. *Parker* of Fleet Street, London. It is made of flint-glass three feet in diameter; but when fixed in the frame, the surface is reduced to two feet eight inches and a half. It is circular, three inches and a quarter thick in the middle, and diminishing in sections of large spheres to the edge, which is thin. The distance from the glass to the focus where the rays meet, is six feet eight inches, and the focus is one inch in diameter. But the refracted rays are made to fall upon another lens thirteen inches in the clear, behind which they unite in a focus only three-eighths of an inch in diameter; consequently the area of the great lens was 7511 times greater than that of the last focus, where therefore the light and heat accumulated must, if the glass could have been made absolutely perfect, have been so many time greater than the natural light and heat of the sun, upon a surface three-eights of an inch in diameter. The glasses are mounted on a frame and stand, to be placed according to the sun's elevation; and the substances on which experiments are to be made, are placed by a part of the apparatus on a small iron plate. The results of some of the experiments made in the presence of men of science by this machine, are the following:—Every kind of wood placed on the plate in the focus, took fire in an instant. Iron plates grew hot in a moment, and then melted. Tiles, slates, and earth of all sorts, became instantly red, and were converted into glass. Sulphur, pitch, and all resinous substances, melted when they were in the focus, although under water. Fire-wood exposed to the focus under water presented no outward change of appearance; but when taken out and broken, the inside was found to be reduced to charcoal. When a hollow was made in a piece of charcoal, and in it were placed the substances to be acted upon, the power of the glass was much increased. Metals thus inclosed in charcoal were melted in a moment, the fire sparkling like that of a forge. The ashes of wood, paper, linen, and all vegetable substances, were turned in a moment into a transparent glass. The substances the most difficult to be wrought upon were those of a white colour, because white is the most powerful reflector of light and heat. All metals were vitrified on a china plate, when it was thick enough not to melt, and the heat was gradually communicated. When copper was melted in this way, and immediately thrown into cold water, it produced a shock so violent as to break the strongest earthen vessel, and the copper was entirely dissipated. A piece of pure gold weighing 20 grains was melted or fused in 3 seconds of time; pure silver 20 gr. in 4 sec.; pure copper, 33 gr. required 20 sec.; platina 10 gr. was fused in 3 sec.; bar-iron in a cube of 10 gr. in 12 sec.; cast-iron in a cube of 10 gr. in 3 sec.; steel in a cube of 10 gr. in 12 sec.; an oriental emerald of 2 gr. required 25 sec.; but a crystal pebble of 7 gr. was fused in 6 sec; white agate 10 gr. in 30 sec.; oriental flint 10 gr. in 30 sec.; rough cornelian 10 gr. in 75 sec.; rotten stone 10 gr. in 80 sec; common slate 10 gr.

in 2 sec.; lime stone 10 gr. in 55 sec.; lava 10 gr. in 7 sec.; moor stone 10 grains in 60 seconds.

Although the heat of the focus was so intense as to melt gold in a few seconds, yet the finger, it is said, could be placed in the cone of rays, within an inch of the focus, without receiving injury: this however requires confirmation. A person had the curiosity to try what was the feeling of burning in the focus, and placing his finger in it, he reported the sensation to be very different from that of a burning by a fire or a candle, being exactly like the sharp cut with a lancet. By a burning-glass a piece of wood may be charred, in the midst of a decanter of water, and yet the sides of the decanter will not be cracked or otherwise affected, nor will the water be at all warmed, not even if the wood be taken out, and the rays collected in a focus in the water. If however a piece of metal be introduced, it soon becomes too hot to be touched, and communicating heat to the water will make it even boil. It is on account of the metallic substance of the vitriol in ink that water may be heated by the glass, when a little ink is mixed with it.

Down to the time of Sir Isaac Newton it was believed that light, in passing from one medium into another, was all equally reflected; but he discovered that light was not one simple body entirely homogeneous or of the same nature; being composed of different parts, which underwent different degrees of refraction, and thereby excited in our minds the ideas of different colours. The separation of a ray of white light into its component parts may be witnessed in this easy way:—Let a room exposed to the sun be darkened, so that no light can enter but by a small hole made in the window shutter. Let the ray of light from the hole fall upon the perpendicular side of a triangular solid piece of clear glass or prism, and at a convenient distance placing a sheet of white paper, the ray will be thrown up upon it, after refraction through two sides of the prism, not in a circle of white light, but in an oblong figure, standing perpendicularly, and containing different colours and occupying different portions of the figure or spectrum. If the upright length of the spectrum be divided into 360 equal parts, the several colours, beginning at the lowest, will appear in the following order and proportion:—The lowest is red, occupying 45 of those parts, the second is orange, 27; the third yellow, 48; the fourth green, 60; the fifth blue, 60; the sixth indigo, 40; and the seventh or uppermost is violet, 80. Among the many interesting inferences suggested by this arrangement, it may be here observed that, if the fifth light blue, and the sixth dark blue be considered as different shades of the some colour, it will hold true that a mixture of two alternate colours will produce the intermediate colour. Thus the first red and the third yellow, give the second orange; the third yellow, and the fifth and sixth blue, give the fourth green; the fifth and sixth blue and the first red, will produce violet of different shades, &c. From these facts it would appear that the component parts of a ray of white light may be reduced from seven to three, viz. red, yellow, and blue, by different combinations of which all other colours and tints may be produced. When these coloured rays are duly united they produce white; and although we are in the habit of considering its opposite black as also a real colour, yet it is in fact merely a term by which we would express the negation or absence

of all colour together. When all light is excluded objects of every colour appear black, or, to speak more correctly, they wholly disappear; and in such a case, by darkness and blackness, we mean not that the objects have lost or changed their several colours, but that in the absence of light their colours are imperceptible. Hence we are led to another inference, that colours are not real qualities, inherent in the several substances of which the objects are composed, but modifications of light produced by the nature of the component particles of those substances, refracting and reflecting particular portions of light, according to the peculiar structure and position of those particles.

The separation of light into seven different colours, by the triangular glass prism, was already mentioned: if on the other hand we could procure very fine powders exactly of those colours and in precisely the same proportions, and were to mingle them most intimately together, the whole mixture would, in proportion to the perfection of the experiment, assume more and more of a whitish tinge. The same effect will be produced by painting the rim of a wheel in the same colours and proportions, and whirling it about with the greatest rapidity. That different coloured substances possess different powers of receiving or reflecting rays of light and heat was long ago shown by the sagacious practical philosopher Dr. *B. Franklin.* In one of his treatises he furnishes the following instructive statement:—" Let me now mention an experiment which you may easily make yourself. Walk but a quarter of an hour in your garden when the sun shines, with a part of your dress white and a part black: then apply your hand to them alternately, and you will find a very great difference in their warmth. The black will be quite hot to the touch; the white still cool. Another experiment: try to fire paper with a burning-glass: if it be white, you will not easily burn it; but if you bring the focus to a black spot, or upon letters written or printed, the paper will be immediately on fire under the letters. Thus fullers and dyers find black cloths of equal thickness with white ones, and hung out equally wet, dry in the sun much sooner than the white; being more readily heated by the sun's rays. It is the same before a fire: the heat sooner penetrates black stockings than white ones, and sooner scorches a man's shins. Beer much sooner warms in a black mug than in a white one, or in a bright silver tankard. But my principal experiment was this: I took a number of little square pieces of broad cloth, from a taylor's pattern-card, of various colours. These were black, deep blue, lighter blue, green, purple, red, yellow, white, and other colours or shades of colours. I laid them all out upon the snow in a bright sun-shiny morning. In a few hours (I cannot now be exact as to the time) the black being most warmed by the sun was sunk so low in the snow as to be below the stroke of the sun's rays; the dark blue almost as low; the light blue not quite so much as the dark; the other colours less as they were lighter; and the quite white remained on the surface of the snow, not having entered it at all.—But what signifies philosophy that does not apply to some use? May we not learn from hence that black clothes are not so fit to wear in a hot sunny climate or season, as white clothes; that soldiers and seamen who must labour in the sun, should, in the East and West Indies, have an uniform of white: that summer hats should be white to repel the heat, which to many gives headachs, and to some the dreadful and usually-fatal stroke the French call *coup-de-soleil:* that the lower parts

of hats, however, should be black, as not reverberating on the face the rays reflected up from the earth or water: that fruit-walls being blacked may receive so much heat from the sun in the day-time, as to continue warm, in some degree, through the night, and thereby preserve and forward the fruit," &c.

In support of these sensible observations of Dr. *Franklin*, we may notice the surprising fact, well known to all who have climbed, or attempted to climb the lofty *Mont Blanc*, in the Alps, between Italy and Switzerland, that in making their way along or across the deep vallies which furrow the mountain sides, paved and lined with snow and ice, of perpetual duration and primeval antiquity, the air is often so intensely heated by the sun's rays, reflected from the brilliant white surface on all sides, as to become unfit for human breathing and life; while the snow and ice remain almost entirely unaffected by the warmth. From the whole of these remarks it may be concluded that whiteness is produced by the abundant, not to say total, reflection and due proportion of all the colours composing a ray of light; and that blackness proceeds from the peculiar quality of a body which absorbs and stifles the rays falling on it; so that instead of reflecting them outwards, they are as it were reflected inwards, till they are entirely lost. Hence we may see why black and dark-coloured clothes absorb the light and the heat of rays proceeding from the sun or fire, while white and light-coloured clothes reflect both and retain little of either.

The most remarkable example of the refraction and reflection of the rays of light is given in the *rainbow*. This magnificent phenomenon is generally produced by the reflection and refraction of the sun's rays, from and through the globular drops of rain. Similar appearances are also produced, although very faint, by the light of the moon. The broken water of the waves of the sea, and even the dew on the ground, show the same effect, as do cascades and fountains; and water blown violently from the mouth of a person standing with his back to the sun, will exhibit a rainbow. Of the same kind are the *halos* or circles about the moon, and the everchanging colours seen on a soap-bubble.

Of the Eye. This admirable organ acts precisely as an optic lens: it is of a globular form; but more protuberant before than in any other part. It consists of three coats inclosing different substances or humours, the outermost from its toughness, called *sclerotica*, being strong elastic and white like parchment; the back part is thick and opaque, growing thinner as it approaches the front which swells out and is perfectly transparent: this convex part is the *cornea*, from its resembling the clear horn of a lantern. The next inner coat is the *choroides* so called from its abounding in small vessels. Like the sclerotica it consists of two parts, the fore part being the *iris*, which begins at the same place with the cornea. The iris, called also the uvea, consists of two kinds of fibres, the one set tending like rays to the centre, and the other set forming a number of circles round the centre. This centre is pierced through, and the opening called the *pupil*, may, by the action of the fibres, be enlarged or contracted, according as the light proceeding from an object is weak or strong: in different persons the iris is of different colours, black, blue, brown, hazel, &c. The whole of the choroides being opaque, no light can enter the eye but through the opening of the pupil. The third membrane of the eye is the *retina*, because it is

spread like a net all over the interior part of the choroides. This fine and delicate membrane proceeding from the optic nerve, serves to receive the images of objects, produced by the refraction of the different humours of the eye, represented on its surface. From the hinder and lower part of the retina proceeds the optic nerve, which conveys to the brain the sensation occasioned by the rays of light striking upon the retina, itself an expansion of that nerve; a strong proof this that light is a real, although inconceivably subtile material substance. These coats of the eye inclose three transparent substances or humours, the *aqueous*, the *crystalline*, and the *vitreous*. The aqueous humour, so called because it is the most fluid and clear like water, forms the front of the eye in which swims the iris. The crystalline humour is as transparent as the purest crystal, but hard like a strong jelly: its form resembles a double convex lens. The vitreous humour is so named from its being like melted glass, and fills the whole interior of the eye, behind the crystalline.

To conceive how vision or sight is performed, suppose an object placed at a proper distance, with its centre on a right line passing through the centre of the eye. From what was said of double convex lenses, amongst which are to be classed the humours of the front of the eye, rays from every point of the object will fall upon the cornea, and passing through the humours and the pupil will be converged to as many corresponding points on the retina in the back of the eye, where an accurate image of the object, but inverted, will be represented. But if the image be thus turned upside down, how comes it, we may ask, that we see objects in their real position? Of this fact various explanations are given; but after all it may perhaps be best accounted for from experience. Children have in this way learned to understand the true position of objects, long before they can explain, or even inquire into the process by which they do so; and instances of blind persons being restored to sight, after they came to full years, are too rare to furnish the proper information. It was from experience that the young man, whose eyes were first opened by Chesselden, learned to judge of the distances, forms, and colours, of objects; but what his notions were respecting their inverted positions, we are not told.—When I stand before a mirror with a glove in my right hand, the image in the glass looking out to me has also a glove in the hand directly opposite to mine: but if a person were really standing before and facing me, the glove in his right hand would be on the other side opposite to my left hand. From constant experience therefore, acquired in early infancy and long continued, do we learn instantaneously and almost instinctively to place objects in their real position, notwithstanding the inverted position of their images in the eye.

It is not the least admirable circumstance in the structure and application of the eyes, that although both are directed to one object, and consequently images must be figured on the retina of both, yet but one sensation is excited in the brain. For when the axis of both eyes are directed to the same object, and two sets of rays enter each eye, still the effects produced by them on the optic nerve of each eye, are united in one identical part of the brain: consequently the senation of one and the same object only is excited; but this sensation will be twice as powerful as if the object had been seen by one eye only. If

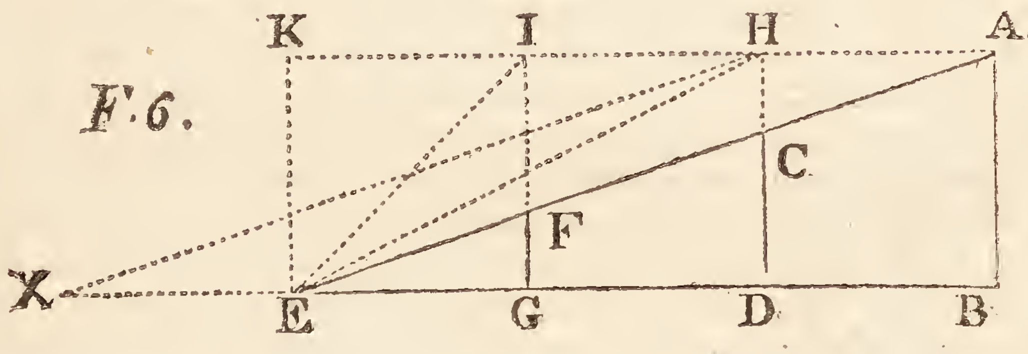
both eyes be not similarly turned to the object, two images will be formed, and vision will be confounded.

Spectacles. It was before observed that the rays of light passing through a thin and perfectly flat glass, every where of equal thickness, are considered to undergo no change: if, however, the glass be ever so little thicker in the middle than at the edges, or convex, the rays will meet in a point more or less distant from the glass as it is less or more convex. The magnifying power is therefore in proportion to the convexity. We judge of the magnitude of objects by the angle formed at the eye by rays from its extremities. From a small object, as a printed letter of a word in a book, but few rays can go directly through the pupil of the eye; but on a glass of an inch in diameter many more rays will fall, and if it be convex they will be collected in a point, in such a way as to pass through the pupil, and give a very complete representation of the object; and the greater the surface of the convexity, the greater will be the number of rays assembled on the retina. By this process as many rays are collected in the eye from a letter of one-eighth of an inch in height, as would have gone directly to the retina from another letter of twice or thrice the size. The nearer any object is brought to the eye, the greater is the angle under which it is seen, and the more it will be magnified in our imagination. But this nearness to the eye is limited; for when an object is nearer than about six inches, vision becomes indistinct with the generality of people. By the help of convex glasses, however, we are able to view things much closer to the eye: for objects being distinctly visible when in the focus of the glass, the greater the convexity of the glass, the nearer is its focus, and the more powerfully will it magnify. If the cornea or the crystalline humour of the eye, or both, be too flat, the rays that pass through the pupil will not converge upon the retina, but behind it: the sight of the object must of course be imperfect and indistinct. To remedy this evil a *convex* glass of a proper focal distance must be placed before the eye to refract the rays towards the centre ray, and so cause them to meet sooner than they did before, and therefore make the proper image on the retina. If on the other hand the cornea or crystalline humour be too convex or protuberant, the rays passing through the pupil will meet in the vitreous portion of the eye, before they reach the retina, and an equal indistinctness of vision will be produced. This is to be remedied by placing a *concave* glass before the eye, which by diverging the rays will prevent their meeting until they arrive back at the retina. The different distances at which different persons, or the same persons at different periods of life, can see distinctly, or the length of their sight, must depend on the convexity of the cornea and crystalline humour of the eye. The rounder these are, the nearer will be the focus or meeting of the rays, and the nearer must be any object, in order to be distinctly seen. Short-sighted people have the eye more than commonly protuberant in the front, which having a short focal distance requires objects to be brought very close to the eye. Long-sight, on the contrary, most commonly produced by age, which flattens the front of the eye, signifies that the focal distance is greater than it ought to be: objects must therefore, to be distinctly seen, be removed from the eye. Hence we see old persons hold objects far off from the eyes, and short-sighted people holdclose to the

eyes the objects examined. Both these extremes are inconvenient; but the aged are to recollect the advantages and pleasures they enjoyed in their earlier days of perfect sight, and be thankful that relief is to be obtained by employing a machine, so admirably simple as well as useful as common spectacles. The short-sighted ought, on the other hand, to be grateful for these two important advantages: that in youth they can distinguish much smaller objects than the long-sighted, and that age by flattening their eyes will improve them, while others are obliged to have recourse to magnifying glasses.

Spectacles in frames ought not to be placed in the same straight line as is the common way, but pointing a little outwards at each end, or in the arch of a great circle with the convexity turned towards the nose. For the two eyes being directed to the same object the lines of sight cannot be parallel, and unless the glass be placed at right angles to those lines the sight must be imperfect. The large reading or hand-glass is only a more powerful spectacle-glass. Another material error in the construction of common spectacles is that the glasses are made by far too large. This will be manifest when we consider how small the pupil of the eye is, and that more light upon the eye than can enter the pupil can be of no use. If the aperture of the glass were no greater than that of the pupil, the object seen would be very distinct; but in many cases there might not be sufficient light to observe it, and the field of view would be much too confined. If, however, the aperture of the glass be three-fourths of an inch, it will answer every purpose of reading, working, &c.: and the light admitted will be but one-fourth part of that received unnecessarily by common glasses of one inch and an half in aperture. The injury produced by improper spectacles is not immediately perceived; but when after long use of them the sight comes to be sensibly impaired, it is considered as the natural consequence of age; although the greater part of the evil be occasioned by the too great body of light thrown upon the eye, and the glasses being placed in the same straight line, the direction of the sight is never at right angles to the position of the glasses.

F. 6.



That objects are only in appearance, and not in reality enlarged or magnified, by convex lenses or glasses, will be manifest from a consideration of the annexed figure. Let A B be any object two feet in height from B, the level of the eye at E at a distance of six feet. The apparent magnitude of A B will be represented by the angle A E B, formed by the extreme rays A E and E B. Suppose two other objects of similar forms be placed at G two feet from E, and at D four feet from E, each being respectively of such a magnitude, as F G and C D, that they will just fill the space comprehended within the bounding rays

E A and E B. In this case the three objects subtending an equal angle at the eye will consequently all appear of the same magnitude; and if the observer were ignorant of their several positions he might consider them to be all standing together joined, and therefore equal to A B. We know, however, by the rule of proportion that if A B distant six feet, be two feet high, C D distant four feet must be one foot four inches, and F G distant two feet must be eight inches high. We have, therefore, three objects all apparently of the same bulk, although the one be but one-third and the other two-thirds of the largest.

Let the parallelogram E K A B be completed, produce G F to I, and D C to H, and draw I E and H E: and changing the magnitudes and distances of the objects, let A B be an object of the height of two inches, placed at the distance of distinct vision, or six inches, from the eye at E, in which are conveyed the rays proceeding from the object. Let now A B be brought nearer to the eye and occupy the place of D C H; the angle of apparent magnitude will be H E D greater than A E B; but being within four inches of the eye the focus of distinct vision will be moved back to X, two inches behind E; the image at E will therefore be imperfect. If however by introducing a convex lens between E and D C H, the rays be made to converge at E, the object will be distinctly perceived, with this additional advantage that it will be seen under an enlarged angle H E D. Suppose the object moved to I F G, within two inches of the eye; the focus of distinct vision will be carried back beyond X to a point four inches behind E, and the object will be very indistinctly seen. If, however, by a lens of great convexity the rays from I F G be converged at E, the object will be seen under the great angle I E G, and consequently the whole and every particular part of it will to the eye appear greatly magnified. Now to apply this reasoning; A B in height two inches, at the distance of six inches from E is seen under the angle A E B, which is found by trigonometry to contain eighteen degrees twenty-six minutes. But when A B is brought to H C D it is seen under the angle H E D, of twenty-six degrees thirty-four minutes, which at the proper distance, six inches would comprehend an object three inches in height. Again, when A B is brought to I F G it subtends the great angle I E G, of 45 degrees: but an object seen under such an angle at the proper distance of six inches, would, in fact be six inches in height: consequently an object of a certain magnitude at the distance of proper vision, will, when brought by a convex lens to the focal distance of four inches, be enlarged one-half, and when within two inches of the eye, be enlarged to three times its original size. But if A B instead of a line be a surface as a square of two inches a side, the area will be four inches; one of three inches will contain nine inches; and one of six inches will contain thirty-six square inches, or nine times more than one of two inches. Consequently by means of the convex lenses the same effects are produced in the eye as would be produced by examining at the point of distinct vision an object really so many times larger than A B: and not only the whole object, but each particular part being proportionally enlarged, what at six inches was just discernable by the eye, may by a lens be enlarged so much as to be perfectly seen and distinguished. When it is considered that by increasing the convexity of a lens, its magnifying power is gradually nicreased, and that by combining two, three, or more lenses together, that

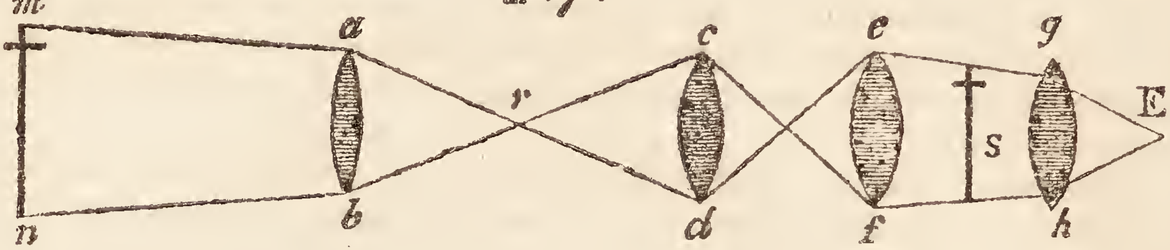
power will receive still farther augmentation, the magnifying powers of glasses must, in theory, be unlimited. In practice, however, from the imperfection of the substances of which the finest glasses can be made, from the reflections and peculiar refractions of their parts, and from other causes, by which a great part of the rays of light are dissipated and lost, our power of enlarging objects comes far short of what might be expected. On this head it has been deemed proper to write at some length, because on it is founded the whole doctrine of magnifying glasses, from the common spectacles to the most perfect telescope to explore the most remote corner of the heavens, and the most powerful microscope by which we can examine the most minute particles of objects around us.

Telescopes. This admirable instrument is so named from two Greek words *tèlé* at a distance, and *scopos* one who views, because by it we can descry and examine objects far beyond the bounds of natural sight. The power of a single lens or convex lens, in collecting the heat of the sun, it was already said, was known to remote antiquity: yet it is equally true, though difficult to conceive, that the same ancients should know that such glasses would burn, and not find out that they also magnified. This, however, may have been owing to the form of their burning-glasses, which are described as balls or globes, some of them solid glass or crystal, others hollow and filled with water. Now it is known that a globular lens, causes the rays passing through it to converge very near its surface, namely at one fourth part of their diameter. Supposing then an ancient lens to have been even six inches in diameter, the focus of its refracted rays would be placed within $1\frac{1}{2}$ inch of its surface, so that the magnifying power might long remain unobserved, for unless both the object and the eye had been placed at that short but precise distance from the opposite sides of the globe, the magnifying property could never be perceived. It is in fact much more wonderful that, in later times, when science had made much greater progress, nearly three centuries should have intervened between the invention of spectacles at Pisa in Italy in 1299, and that of telescopes in Holland in 1590. This discovery, as the story goes, was, like many others of great importance, the fruit of accident, and not of scientific research and experiment. A boy and a girl, children of *Jansen,* a maker of spectacles in Holland, at play in his work-shop with some glasses of which they knew the magnifying property, observed, that by looking through two glasses the one concave, and the other convex, at a certain distance asunder, the objects appeared much larger than when seen through a single glass. Telling this fact to their father, he immediately contrived to place two or more glasses, first in an open frame, and afterwards, in order to exclude all side-light, in a tube, and the telescope was brought into existence. This grand discovery was soon spread abroad, and in 1610 the celebrated *Galileo* of Florence, by a telescope of his own contrivance, had a view of the moons or satellites, that roll round the planet Jupiter.

Telescopes are of different sorts, according to their nature and properties: the original was of course refracting, and had the disadvantages that it admitted but a small field of view, and that all objects appeared inverted, which rendered it unfit for examining such as were on the earth; in celestial researches it was of great use. In the *refracting telescope* the glass next to the observer is called the eye-glass, and the one

at the other end is the object-glass. The magnifying power of this instrument is found by dividing the focal distance of the object-glass by that of the eye-glass; thus if the focal distance of the object-glass, or the distance between the glass and the point where the rays are converged be 100 inches, and that of the eye-glass be $2\frac{1}{2}$ inches, the quotient is 40, the number of times that such a telescope will magnify any object.

F.7.



Telescopes for viewing terrestrial objects and representing them, not inverted, but in their natural positions, are made as is shown in the above figure, in which E is the eye, and *m n* is the object to be viewed; *a b* is the object-glass, and *c d e f* and *g h* are three eye-glasses, placed so near each other, that the rays passing through any two will meet in the same focus; that is to say the rays refracted from *a b* and *c d* for instance, will meet in the common focus *r*. A ray from the upper part of the object *a* will, on entering the object-glass *a b*, be refracted down through the focus *r*, and enter the lens *c d*; thence it will be refracted upwards through the common focus to the lens *e f*. Again a ray from *n*, the other extremity of the object, will, by passing through the same glasses, be also refracted to the lens *e f*; consequently if all the rays proceeding from the object be converged as in the image *s*, that image will be seen by the eye E through the outer glass *g h*, in the same erect position as it is in nature at *a n*, and the rays refracted from *g h* will enter the pupil, and be painted on the retina as before. The three eye-glasses have all the same focal distance; and the magnifying power of the telescope is found by dividing the focal distance of the object-glass by that of any one of the eye-glasses, as was before said.

When the rays of light are separated by refraction they are coloured; but when united again they become white as at first. Those rays, however, which pass through a convex glass, near the edges, are more unequally refracted than those passing towards the middle of the glass. Rays thus unequally refracted will not meet in the same focus, and the image they form will of course be coloured at the edge and indistinct. To remedy this defect, a plate with a small round hole in the middle is fixed in the tube of the telescope, at the place of the image *s*, by which the wandering rays are stopt, and none but those from round the middle of the lens *e f* can pass through. This advantage is however in some measure compensated by the lessening of the field of view, which would be much larger without the perforated plate.

Telescopes by their magnifying property seem to bring distant objects near to the eye. A man at the distance of two hundred yards will by a telescope magnifying a hundred times appear as distinctly as if he really were only two yards off. If he does not appear to be enlarged to a gigantic size, it is because all the objects around him being equally magnified with himself, every object is presented in its

just proportion. The magnifying power of a telescope may be found by means of two equal circles drawn upon paper, an inch or more in diameter. Fix one of them on a wall 100, or 150 yards off, and the other at a short distance from you, nearly in the same line. Then look at the farthest paper through the telescope with the one eye, and at the nearest paper with the other eye naked; moving it backwards or forwards until the two circles appear quite equal to the two eyes. Measure the two distances from the eye-glass of the telescope to both circles; divide the greater distance by the less, and the quotient will give the magnifying power of the instrument. To try an object-glass, place it in a tube, and with different eye-glasses, examine some objects placed at a distance, particularly the title-page of a book. The object-glass which shews the objects the most bright and distinct, admitting the greatest field of view, with the eye-glass of the shortest focus, without colouring or dimness, is the best. When several telescopes of the same length are compared together, those are the best with which you can read the same print at the greatest distance; a simple experiment for the guidance of any one who buys a telescope.

The perfection of refracting telescopes consisting in their length, at last the use of a tube to contain all the glasses was laid aside, and a method was discovered by *Huygens*, of Holland, to make the instrument of great length, but easily manageable. He fixed the object-glass on the top of a long upright pole, directing its axis towards any object by means of a silk line connected with the eye-glass below. In this manner telescopes, although not formed of one continued tube, were made of the length of 120 feet and upwards. *Dr. Derham* of Upminster in Essex, possessed a refracting telescope of this sort. To enable him to use it in examining celestial objects, much elevated above the horizon, it was proposed to furnish him with the tall maypole then adorning Charing Cross in London. His treatises on Astro-theology and Physico-theology are still deservedly popular; although many and important alterations and additions have, since his time, been introduced into the subjects on which they treat, of which an excellent summary will be found in *Archdeacon Paley's* elements of natural theology.

The imperfections of even the most improved refracting telescopes were so numerous, that ingenious men in different parts of Europe set themselves to devise some other machine that might better answer the same purposes. At last *Dr. James Gregory*, professor of geometry, first at Aberdeen, and afterwards at Oxford, produced a telescope in which objects are represented, not by the refraction, but by the reflection of the rays of light proceeding from them. This admirable instrument immediately obtained the complete approbation of Newton, and other eminent philosophers; and upon this original scheme are founded all later reflecting telescopes. A reflector of only six feet in length may be constructed equally powerful with a refractor of a hundred feet. The Gregorian, catadioptric, or reflecting telescope, is constructed as in the longitudinal section shown at Fig. 1. of Plate 4th, to which the following description refers. ABFGHICD, is a section of the eye-end of a reflecting telescope. BC is the great mirror, of which the section is a portion of a parabola on each side of the principal axis. In the centre of this mirror is a circular aperture *a c*, and opposite to it is a small mirror *e n*, supported on a strong wire reaching to the side of the tube at A, where it is connected with an adjusting screw extending

along AB, by turning which the small mirror may be placed at a proper distance from the great mirror, to suit the eye of the observer placed at E, at the end of the small part of the tube. The rays of light proceeding from any very distant object, as from the moon or a planet, may be considered as all arriving in the telescope in a parallel direction. Thus the ray *r* will fall on the great mirror near B, be thence reflected to the small mirror at *n*, and there be again reflected through the aperture *a c*, upon the plano-convex glass F I, whence upon refraction, it will proceed to the similar eye-glass G H, and there lastly be refracted to the observer's eye at E. In the same way the ray *s* will fall on the great mirror near C, be reflected to the small mirror at *e*, and thence be refracted through the eye-glasses to the eye at E. In the same manner the whole body of rays from the distant object which enters the telescope, will, after reflection from the two mirrors, and refraction through the lens F I, form the image *o t*, which will be in the same attitude and position with the original object. The rays from *o* and *t*, the extremities of the image, will, upon refraction through G H, enter the eye at E in such directions as if they really came from the points *x* and *z*: the image *o t* will therefore be beheld under the great angle *x* E *z*, and will consequently appear enlarged to *x o t z*; all parts of which being so near to the eye, may be perfectly discernible.

In comparing the powers of telescopes of different constructions, it may appear to be possible to endow them with any assignable magnifying capacity; we have only to choose an object-glass of the greatest power, and an eye-glass of such convexity as to convey the image to the eye, under the greatest possible angle. This is doubtless all true in theory; but in practice it is unattainable. The principal causes of this limitation are, 1st. the extreme difficulty of forming mirrors of concavity perfectly parabolical; and 2d. that a ray of white light, as was before stated, consists of different parts, not only of different colours, but susceptible of different degrees of refraction. The consequence of this is, that the image formed by such rays not meeting in the same focus, must be confused, indistinct, and tinged with the several colours, produced by the parts of each ray. To remedy this imperfection, a most effectual method was communicated to the world by the ingenious optician *Dollond* of London, who, by a combination of convex and concave object-lenses, contrived to balance their opposite refractions. Telescopes of this kind admit a large aperture, by which a greater number of rays are received, and a higher power of magnification may be produced. From their preventing in the image the colours occasioned by unequal refraction, Dollond's telescopes are said to be *achromatic*, (a word often senselessly printed *acromatic*,) from a Greek term signifying devoid of colour.

Microscopes. The telescope is fitted to view large and distant objects: the microscope, on the other hand, enables us to examine other objects small and at hand, agreeably to its Greek name; for *micron* is any thing of small bulk. Microscopes are either single or compound, or solar. The *single* is merely a double convex lens, having the object in the one focus where its refracted rays meet, and the eye in the other focus: its magnifying power is found by dividing six or seven inches, the shortest distance of natural vision, by the focal distance of the lens. Suppose the rays to be assembled in a focus $\frac{1}{8}$ part of an inch from the lens, and that I can see the object without any help

Plate 4

Fig. 1.

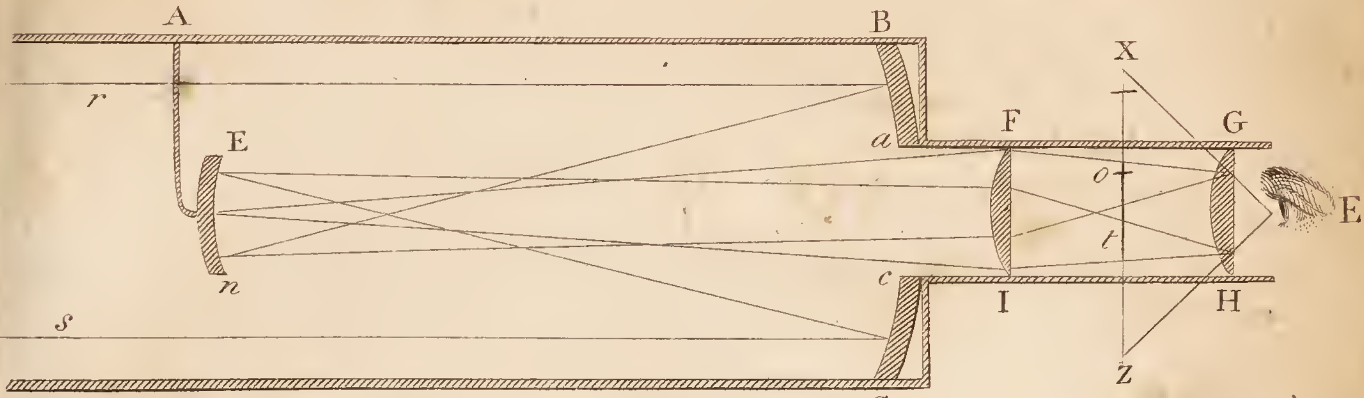


Fig. 2.

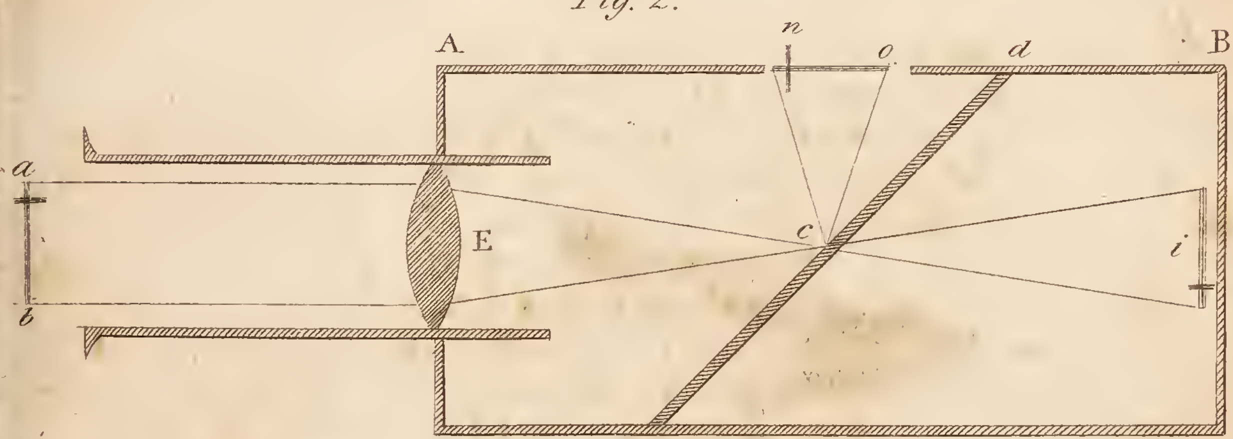


Fig. 3.

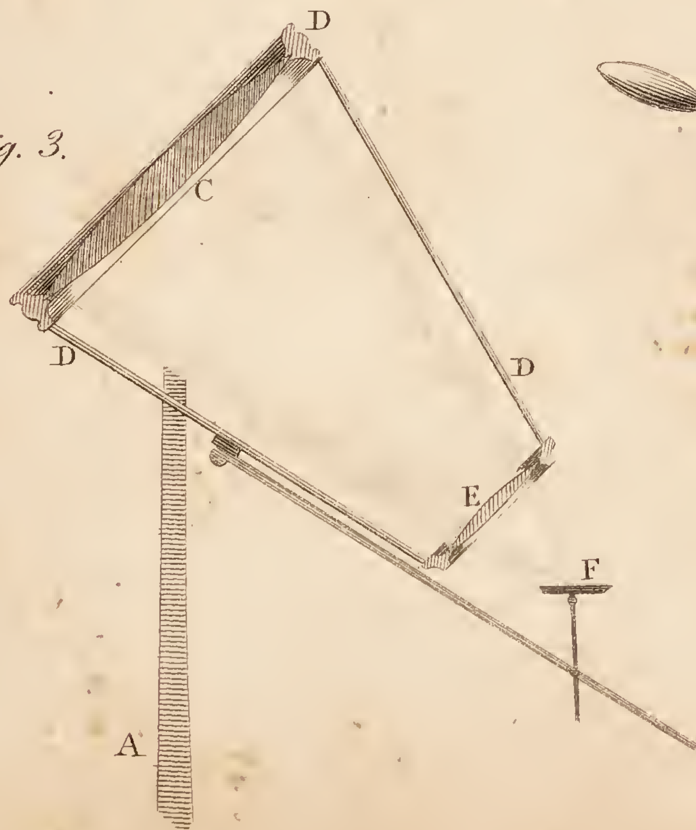


Fig. 4.

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I. Brown. sculpt.

at six inches, this divided by $\frac{1}{8}$ will give forty-eight for the power of the glass. To another person who is short-sighted, and can see an object at five inches, the lens will magnify only forty times; but to one of long sight who sees best at seven inches, the same lens will magnify fifty-six times.

The *compound* microscope contains an object-glass, and an eye-glass. The object to be viewed is placed a little farther off than the focus of the object-glass, that the rays from it may, after passing through the glass, converge on the other side, and form an image which is viewed through the eye-glass so placed, that one focus is at the image, and the other at the spectator's eye. In this microscope the field of view is very confined, wherefore it is usual to employ two eye-glasses, placed at a short distance asunder. The magnifying power of the compound microscope depends on the difference of magnitude between the object and its image, and the shortened distance at which the eye can view the object. Thus if the object can be seen at the distance of $\frac{3}{4}$ of an inch, while the natural eye would require six inches, or eight times that distance, and the image be six times larger than the object, by multiplying these two numbers together, we have forty-eight for the magnifying power of the microscope on a line, and the square of 48, or 2304, for the magnification of the surface of the object. When the glasses are fixed in a tube upon a stand, the object to be examined is placed on a plate or stage immediately under the tube, having an aperture in the middle through which comes up a strong light reflected from an inclined mirror below. This is the common construction of microscopes: but various other forms, and ways of arranging the several parts may be adopted.

The *solar* microscope is so named, because it is used only when the sun's light is very strong. On the outside of a window is placed a plane mirror, inclined to the sun's rays at such an angle, as to reflect them upon a double convex lens fixed in the shutter, through which they are refracted to a focus at another small lens at the inner end of the tube. Between the two lenses, and in the focus of the least is placed the object which, being powerfully illuminated from the external mirror, is refracted through the little lens, and greatly magnified on a white cloth or other proper substance. The magnifying power of the solar microscope is regulated by the distance of the cloth from the window. Eight or nine feet will be sufficient; and the size of the image will be to that of the object, as the distance of the image from the little inner lens is to that of the object.

The *Camera-obscura*, or *Dark-chamber*, is produced by fixing a double convex glass in the shutter of a window of a room, from which all light is totally excluded, excepting what passes through the glass. The window should, in our parts of the world, be exposed to the north, that all objects on the outside may be strongly illuminated by the noon-day sun, and be seen in the brightest colours. In the focus of the glass will be seen, but inverted, correct images of the houses, trees, animals, ships, &c. on the outside of the window. On this principle is constructed a portable camera-obscura, extremely useful in taking views of landscapes, in the following way.

Let A B C D, Fig. 2. Plate 4th, be the upright section of a rectangular box, in the end of which A D is inserted the double convex glass E, and let *a b* be any external object strongly enlightened by the sun.

A ray from the upper extremity *a* will be refracted through the focus *c* to the opposite end of the box B C, and by means of the rays from the lower extremity *b*, similarly refracted through *c*, will on that end form *i*, the image reversed of the external object *a b*. Suppose now that in *c* be placed the plane mirror *d e*, inclined at an angle of forty-five degrees to the horizon. In this case the ray from *a* will be reflected from *c* in the mirror to the upper part of the box at *n*, the ray from *b* will be reflected to *o*, and the whole rays from *a b* will form the image *n o* horizontal, but in its natural position. This image is received on a piece of plain glass or of oiled paper, fastened in the top of the camera, on which the lines may be traced with a pencil, to be afterwards transferred to other paper. The glass E is placed in a moveable tube to be set to the proper focus.

The common *Magic Lantern* is a machine of the same kind, within which is a lamp, which by its light transmitted through a large plano-convex glass in a tube in the front, strongly illuminates a small transparent painting on glass placed before the lens, in an inverted position. A different sort of magic lantern excited much surprise some time ago, under the name of *phantasmagoria* (the raising of phantasms or spectres). In the common machine the figures are painted on glass, the remainder being transparent; of course the image on the screen is a circle of light having a figure in the midst. In the phantasmagoria, on the other hand, the whole of the glass is dark except the figure, which alone appears on the screen, which is of thin silk, and placed between the lantern and the spectator. By moving the light near to or farther from the screen, the image seems to retire or approach; and no part of the screen being perceptible, but the figure only, this seems to be formed in the air, and to be enlarged as if it came nearer to the spectator, and be diminished as if it receded from him; although in fact it be always at the same distance. The *multiplying* glass is cut into a number of faces, through each of which the rays of light proceeding from a single object are refracted in different angles to the eye, which thus instead of one single image seeing a number, is apt to conclude it really sees a number of objects instead of one only.

Explanation of Figures.

Plate II. Fig. 3. represents a compound microscope. A G is the body or internal part, moveable up and down in the outer case C D, supported on three legs as E. The plate or stage F is open in the centre, to admit the light to pass through the glass containing the objects to be viewed; the light is reflected upwards by the inclined mirror H. At G is a magnifying lens, another at B, and the eye-glass at A.

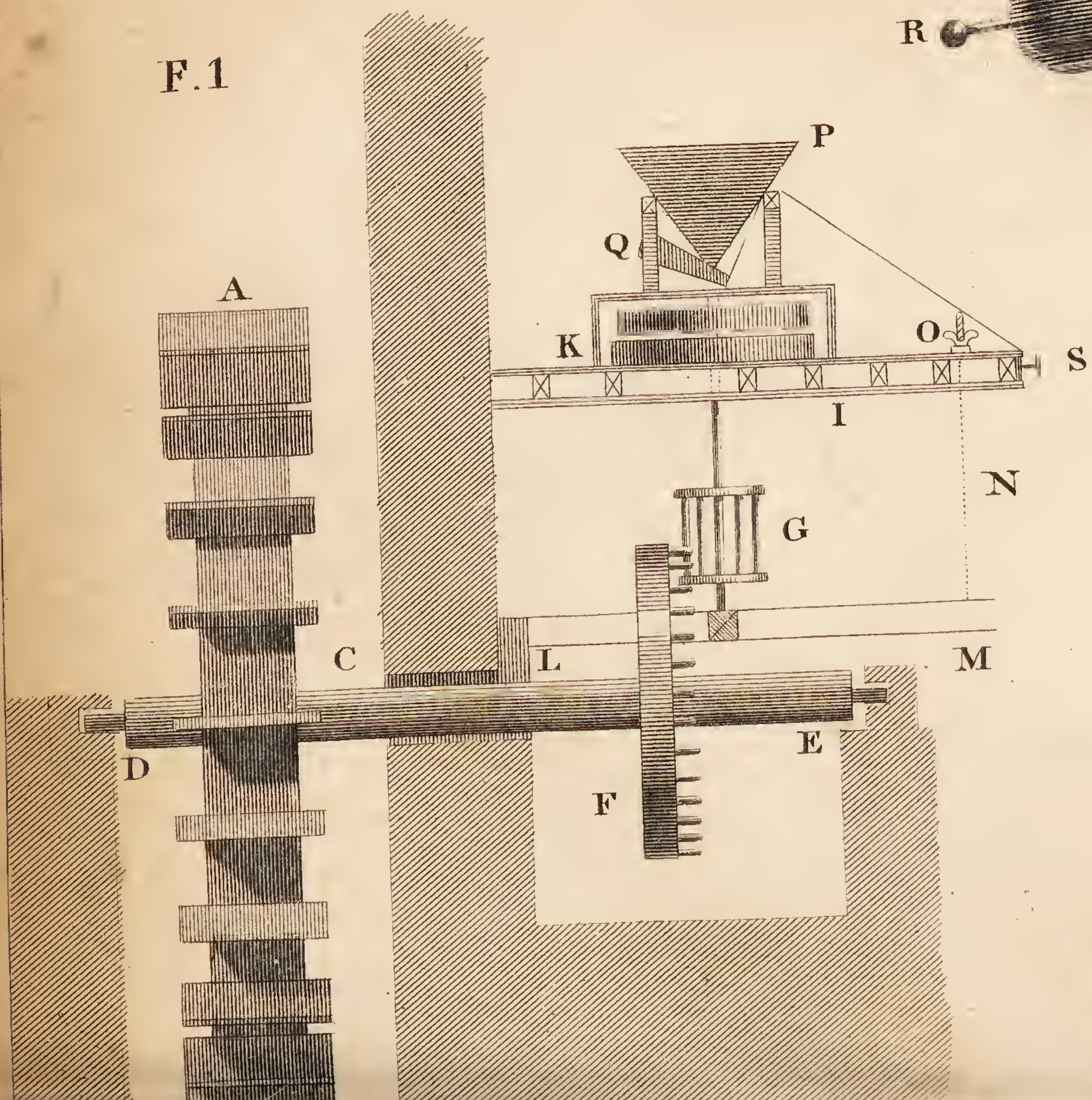
Plate IV. Fig. 1. is a longitudinal section of the Gregorian or reflecting telescope described in the text.

Plate IV. Fig. 2. is a similar section of the camera obscura, also described in the text.

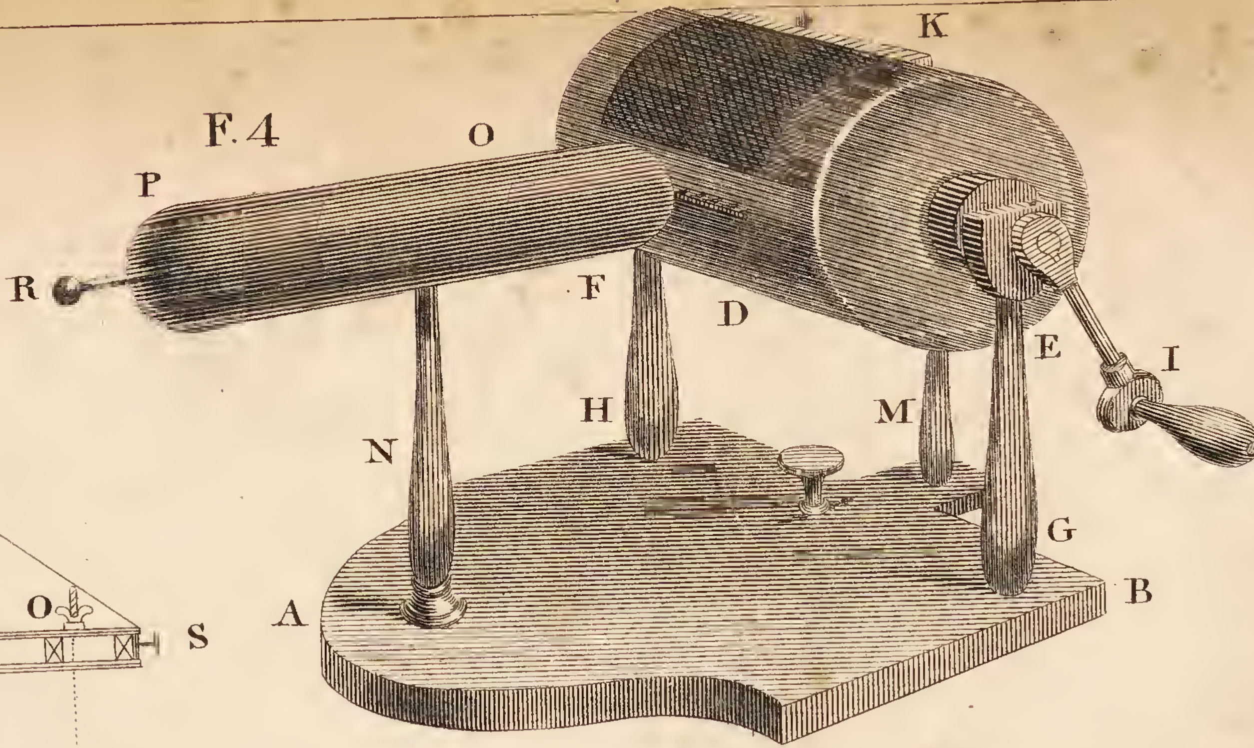
Plate IV. Fig. 3. is a similar section of Parker's very powerful burning lens or glass. The lens itself C is fixed in the circular frame D D, connected with another frame and lens at E. The rays collected by the great lens (as partly shown in the figure,) fall upon the small lens, and are there again converged into the focus at F, which is a stand supporting the object on which the experiments are made. The whole apparatus rests on the fulcrum A.

Plate 2d,

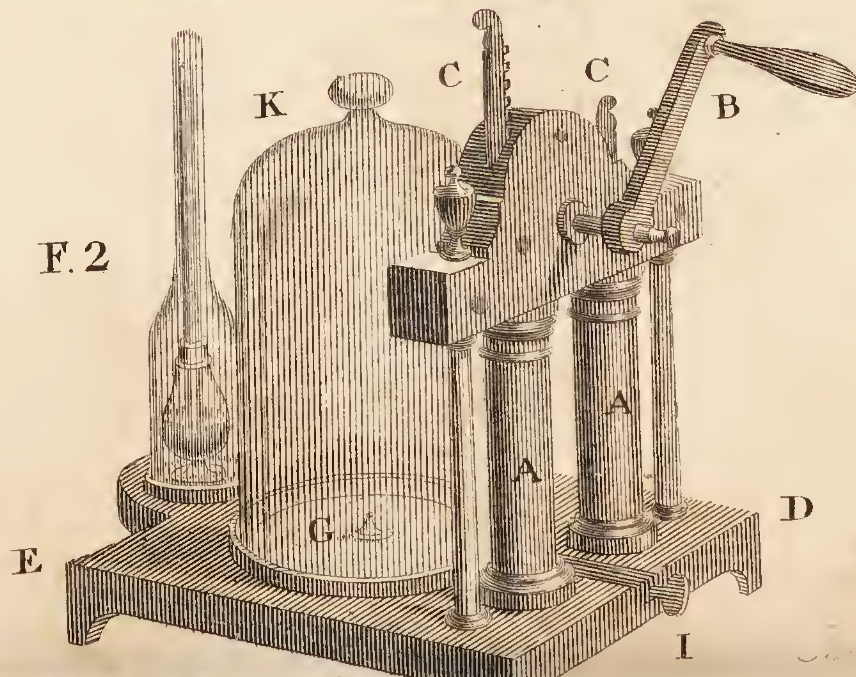
F. 1



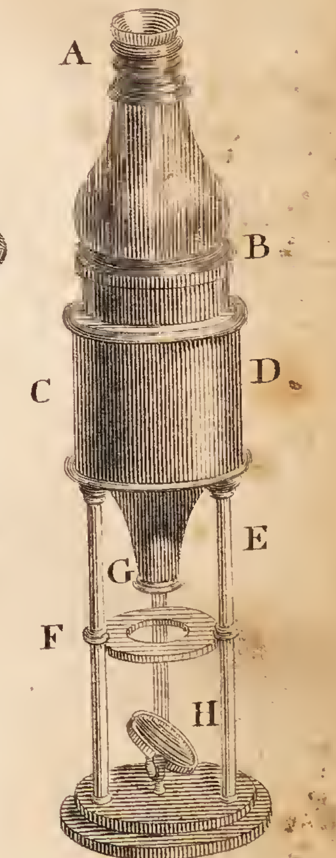
F. 4



F. 2



F. 3



SECT. VI.

ELECTRICITY.

THIS branch of natural knowledge draws its name from *electron,* the Greek term for amber; because from observing certain properties of that substance, men have been led to the discovery and arrangement of facts resulting from other bodies, on which the doctrine of electricity is founded. The Greek *electron,* and the corresponding Latin *electrum,* were also applied to a very different substance, being a compound of gold and silver, more resplendent, says Pliny, by the light of a lamp or torch, than silver itself. Of this metallic composition, cups, statues, and even columns were formed by the ancients. It is however the natural amber to which we now allude.

Amber, or more properly *ambar,* according to its origin in the Arabic language, is chiefly found on the shore of the Baltic sea, in the Prussian dominions; sometimes up the country, resting upon wood-coal, or black charred trees, at the depth of 80, or 100 feet under ground: it is almost completely combustible, and possessing many of the properties of resinous substances, is therefore considered to be of vegetable origin. It is brittle, light and hard, usually pretty transparent, and commonly yellow or even deep brown. It is tasteless, and without smell, unless when pounded or heated, when it emits a fragrant odour. On this account amber is carried from Prussia to the eastern parts of the world, particularly to Persia and China, where it is burned on chafing-dishes, during their festivities, to perfume the chambers of the great. When roasted or exposed to a melting heat, it combines with drying linseed oil and turpentine, and then forms *amber varnish.*

The earliest account we have of the peculiar properties of amber mount up about 600 years before the Christian era, when *Thales* the Greek philosopher of Miletus in Asia Minor, observed that, when heated by rubbing, it attracted straws, feathers, and other light bodies. About 300 years later *Theophrastus* noticed light bodies to be attracted by another substance, when exposed to heat without friction. This he called *lyncurium,* probably what is now called *tourmaline,* a species of shorl consisting of the basis of alum, flint and iron. This stone was first brought from Ceylon in the East Indies about 60 years ago: but is now found to enter into the composition of mountains in various parts, generally crystallized in prisms of 3, 6, or 9 sides. It is commonly green, and partially transparent: when heated to 200° of Fahrenheit's thermometer, (a little lower than boiling water, which rises to 212°) it becomes electric without friction. The *zeolite* possesses the same property.

Down to the end of the 16th century, no farther notice of the properties of these substances occurs in the history of science. In 1590, a treatise on the magnet was published by an English physician, *Dr. William Gilbert,* in which were introduced a number of experiments illustrative of electricity, as well as of magnetism, and containing a list of various substances possessing attractive properties, similar to those of amber. Since that period many ingenious persons have devoted

themselves to the study of electricity, particularly the late *Dr. Joseph Priestley* of Birmingham, and *Dr. Benjamin Franklin* of Philadelphia, by whose labours the science was placed in the way to be afterwards carried on to perfection.

The doctrine and practice of electricity are founded on this supposition, that this earth, and all bodies with which we are acquainted, are endowed with a fluid substance, extremely subtile and elastic. Of this fluid each body possesses a certain share adapted to its nature ; and so long as it contains neither more nor less than its natural share, the electric fluid produces no sensible effect, and is therefore imperceptible. If, however, the natural share be increased or diminished, very striking and important effects are produced : the body is said to be *electrified*, and the electricity becomes apparent. This increase or diminution of the electric fluid, in any body, would immediately be brought to the proper quantity, by communication with other bodies, provided all substances were equally fitted for the transmission of the fluid, which we know is not the fact. Those bodies which permit the fluid to pass through them freely, without retaining it, are called *conductors* and *non-electrics:* while those which retain the fluid in accumulation are termed *electrics* and *non-conductors.* Of this last class of bodies in which the electric fluid is accumulated, the most perfect among solid substances are glass, resins, bees' and sealing wax, sulphur, wood baked to perfect dryness in an oven ; and among fluids air and oils. The best conductors of electricity, or the substances through which it passes with the greatest freedom, are all the metals and water : but all substances become conductors when made very hot. A body possessing more than its natural share of electricity, is *positively* electrified ; and one possessing less than its due share is *negatively* electrified. A body so surrounded by non-conductors, that the fluid cannot pass between it and the earth, is said to be *insulated,* as an island is separated from all other land by the surrounding sea. Thus a piece of metal supported on a pillar of glass or wax is insulated : but if a communication be made between it and the earth, by an iron chain or other conductor, the equilibrium between the body and the earth will be immediately restored, whether the piece of metal contain more or less than its due share of electricity.

The equilibrium of the electric fluid in bodies, is disturbed, or it is made to pass from one to another, chiefly by gentle friction or rubbing of the one against the other ; if this be done by a conductor against a non-conductor the electricity is the most powerfully excited. The fluid will leave the less perfect electric, and pass upon the more perfect. Thus if a smooth glass tube be drawn through the hand, the friction causes the electric matter to leave the hand, and to pass upon the glass, where it is accumulated, in addition to the natural share already in the glass. Neither the glass nor the air being conductors, the superabundant fluid has no way to escape : but if a finger, a piece of metal, or any other conducting substance be presented to the glass thus overcharged, the fluid will immediately pass from it to them, and the equilibrium will be restored as before the excitement. In this case the glass is said to be *excited.*

The quantity of electric fluid which can be assembled in this way being very small, machines have been contrived for producing more powerful friction between electric and non-electric substances, and

called in general *electrical machines,* such as that shown at Fig. 4. of Plate II. of which the following is a description.

A B is a strong board supporting the whole machine, to be secured by screws or clamps to a steady table. The glass cylinder D, quite dry and clean in the inside, is about ten inches in diameter, and furnished with two caps of wood or brass, into which the short necks of the cylinder are firmly cemented. Each of the caps has a projection turning in a hole through a piece of wood, cemented on the top of the glass pillars E G, and F H, firmly secured in the frame A B. To the end at E, the handle or winder I is applied, by which the cylinder is turned round; part of it being glass, the more effectually to prevent the electric fluid from escaping from the cylinder. The rubber K is made of leather or silk stuffed with hair; to which a flap of silk is fastened, which covers a part of the cylinder, to prevent the escape of the fluid. This rubber or cushion, as it is called, is fastened to a spring proceeding from a socket cemented on the top of the glass pillar M, the lower part of which is fixed into a small board sliding in the frame, and capable, by means of a screw nut, of being made to press more or less on the cylinder, as may be required. The glass pillar N, fixed in the frame, supports a tube of brass or tin-plate, called the prime conductor, O P, having at one end a collector or range of pointed wires, to collect the electric fluid from the cylinder, when excited by revolving against the rubber, and at the other end R a wire with a knob, from which can be drawn an electric spark, larger than from any other part of the conductor. This knobbed brass wire is only screwed into the conductor, and may be removed at pleasure. The simple rubber here described produces but a very slight degree of excitation in the cylinder: but its power is greatly increased by applying to it an amalgam or compound of mercury with tin, or still better with zinc.

Besides cylinders, glass globes have also been employed in electric machines; and combinations of wheels to produce a rapid rotation; but these have not answered expectations. Plates of solid glass and circular, when properly constructed, seem to be the most powerful of all; being compact and less liable to be affected by damp. The most powerful machine now known exists at Haerlem in Holland, made by the ingenious *Cuthbertson* of Poland Street, London. It consists of two solid circular plates of glass, each sixty-five inches in diameter, fixed on an axis parallel to one another, and 7½ inches asunder. Each plate is excited by four rubbers; and the prime conductor is divided into two branches, which enter between the plates, and by means of points collect the electric fluid from their inner surfaces alone.

When the cylinder is turned round in the machine by the winder, the friction of the glass against the rubber makes the electric fluid pass into the glass, from which it is conveyed to the prime conductor. The rubber receives a continual supply of fluid from the earth by means of an iron chain or other conductor communicating with the ground. On the other hand if a stick of sealing wax, a roll of sulphur, or a tube of rough glass be drawn through the hand, the fluid in the wax, &c. passes into the hand; and the wax being surrounded by the air which is a non-conductor, remains exhausted, and will take sparks of electric fire from proper bodies presented to it. So great however is the velocity of the fluid, that the direction of its motions cannot possibly be distinguished. In this case the wax, sulphur, &c. are said to be ex-

cited, although deprived of their share of electricity, equally with the glass which is overcharged: because, though their state be reversed, the effects are in many respects similar.

If you turn the handle until the machine be well excited, and present your knuckle or a brass knob to the conductor, particularly at the knob R, you will obtain a spark of electric fire darting from the one to the other with inconceivable rapidity, and a snapping noise or report. If the piece of metal be detached from the earth, or insulated, it will retain the fluid communicated to it; but the sparks from it and from the prime conductor will be diminished. If you stand on the ground, and draw sparks from the conductor, or lay your hand upon it, or hold a chain communicating with it, while the machine is excited to the highest degree; still there will be no accumulation of fluid in your body; for it will pass immediately and silently through you to the earth. On the other hand if you stand on a stool of dry wood, supported on glass legs, or on cakes of rosin, sulphur, wax, &c. your body being now insulated the electric matter cannot pass to the earth, but be accumulated; and sparks may be taken from any part of it, just as from the prime conductor before your connection with it. If another person present his knuckle to you, a spark of fire will be seen, and both will feel a slightly painful sensation or pricking, and the snapping noise will be heard. Every part of your body will, in these circumstances, attract light substances; the hairs of the head or the wig, if loose, will repel each other, some of them even standing upright. If on a plate be laid light pieces of feather or slips of paper, and your hand be expanded over them at a distance of three or four inches, as soon as the machine is turned, the feathers and paper will be attracted, and spring up to your hand. Being there filled with the fluid they will be repelled to the plate below, where the fluid being discharged, the feathers, &c. will be again attracted up to the hand, and again repelled to the plate. Thus will these light bodies fly between the hand and the plate with great rapidity, as long as the electrification is kept up with vigour. If a bundle of hairs or light feathers be hung upon the prime conductor, the moment they are electrified by turning the machine they fly from each other, so that some will even stand erect: but if the conductor be exhausted by the approach of a piece of metal, the hairs, feathers, &c. will immediately fall down to their original state. All bodies possessing the same kind of electricity, whether positive or negative, repel each other in proportion to the quantity they contain. Upon this fact is constructed the electrometer, or electricity-measurer. If two balls of cork, or of the pith of elder, of the size of large pease, be hung by the ends of a silk thread, they will hang perpendicularly, and in contact. But if suspended from the electric machine, when in action, they will repel each other. By their divergence they show the quantity of excitation, and also the nature of the electricity; for if it be positive, by touching the balls with a stick of sealing-wax, they will collapse; but if it be negative the wax will make them separate still wider.

The spark of electricity not only has the appearance of fire, but the power of setting fire to various substances easily inflammable. If spirits of wine be held in a spoon, and a spark be drawn through the spirits, they will catch fire as if lighted by a candle. The inflamma-

tion may be produced by a spark drawn through the spirits by the end of one's finger. Not only are our feeling, hearing, and seeing affected by electricity, but also the smell and the taste. If a pointed brass rod be electrified, by being fastened to the prime conductor, or held by a person electrified, and another person standing on the ground present his nose within an inch or two of the point, he will discover a strong disagreeable flavour like that of burning sulphur; and if he receive the electric fluid upon his tongue he will perceive a taste evidently acid. The more sharply pointed are any bodies, the more easily do they receive or part with the matter of electricity. Thus, if a needle be fastened on the prime conductor, or presented to it by a person on the floor, only a small spark will be obtained by the finger or a blunt piece of metal. When these experiments are made in the dark a flame will be seen at the point of the needle: but the appearance of this flame will be different, according as the point is giving out or drawing the fluid. If the point be giving out the fluid, the flame will be in the form of a pencil or brush, with a rustling kind of noise; whereas when the point draws in the fluid, the flame is much smaller, and resembles a star. Points have also the property of drawing the electric fluid from a body, without any explosion or noise or sparks. This property has been usefully applied in securing buildings and ships from the effects of lightning, as will be afterwards explained. The power of the electric fluid will be exhibited by means of two sharp pointed wires, crossing one another at right angles, and having their ends bent in opposite directions. If these wires be placed on another fixed in the prime conductor, and the machine be excited, flames will appear on the four points, and the cross wires will begin to turn round, in the direction opposite to that to which the crooked points are directed, as if pushed backwards by the discharge of a fluid, in the manner of a gun recoiling upon the explosion of the powder.

The Leyden phial, or electrical jar, is so named from Leyden, a celebrated university in Holland, where its properties were first properly discovered. When a conducting body approaches an electrified body, that side of the conductor nearest to it acquires a contrary electricity, while the opposite side acquires the same electricity with that of the electrified body; consequently the contrary electricities of the two bodies have a strong mutual attraction. When the bodies are sufficiently near, and the attraction sufficiently strong, a portion of fluid or a spark will fly from the one body to the other, so as to restore the equilibrium between them, and the whole conductor will then retain only its due share of electricity. When, however, the non-conducting body is presented to another containing a superabundance of fluid, a similar effect will be produced, they will have opposite electricities, and a spark will fly from the one to the other. But on account of the non-conducting quality this addition of fluid will not spread but remain confined to the spot to which it was communicated. If one kind of electricity be communicated to one side of a pane of glass, or other thin non-conductor, and a contrary electricity to the other side, the glass is said to be *charged*. In this state the opposite sides would always remain, were there no moisture in the air, or other mode of communication established between them. But if a communication be properly made between the opposite sides of the glass, the opposite electricities will mutually destroy one another. When the union between the op-

posite sides of a charged electric is thus produced, it is said to be *discharged,* and the act of union is called the *electric shock.* When a living animal forms the whole or a part of this communication, so that the discharge passes through it, a sudden shock, stroke, or impulse, and a very peculiar sensation is felt, by contracting the muscles through which it passes, which is more or less disagreeable, according to its strength, and to the constitution of the person. In order to communicate electricity to the whole of a non-conductor, each part must be brought into contact with the electrified body. But this trouble is saved by coating or covering the sides of the non-conductor with some conducting substance, such as tin-foil, by which the electricity is immediately spread over the whole tinned surface. These coatings must not be permitted to come near each other, at the edges of the glass, lest a communication between them be made through the air. The thinner the glass the higher will be the charge, but the more liable is it to be broken by the attraction of the opposite fluids. The Leyden phial (Fig. 4. plate 4.) is usually a jar with a wide mouth, such as is used for pickles and preserves. To the mouth is fitted a piece of mahogany or cork, nicely turned and varnished. Through the centre of the cork passes a brass wire with a knob at the top, and a small chain at the lower end reaching to the bottom of the jar, which is coated or lined inside and outside with tin foil, up to within a few inches of the neck. To charge this jar a communication is made between the electric machine and the knob on the outside of the mouth, while the outside of the jar communicates with the earth by the table or the hand. After a few revolutions of the cylinder, it is charged and ready to exhibit its usual effects. To discharge the jar by making a communication between the inside and outside coatings, an instrument is employed consisting of a semicircular bent brass rod or wire with a knob at each end, and connected in the middle to a glass handle which prevents the electricity, in its passage between the sides of the jar, from entering the person who performs the operation. One of these knobs is applied to that on the wire that enters the jar, and the other to the outside coating. By this channel the superabundant electricity in the one side of the jar passes to the defective side on the other, with extreme rapidity, in the form of a very vivid flash, accompanied by a loud report.

The most convenient way for a person to receive a shock of electricity is to place the jar or phial, when properly charged, upon a piece of chain laid on the table; then laying one hand on the chain to touch the knob of the jar with a piece of metal in the other hand. Any number of persons can receive a shock together, by holding one another by the hand in a circular order, the first person in the rank communicating with the outside of the jar, and the last touching the knob connected with the inside. In this case every person will receive the shock at the same instant, and nearly in the same degree, although from natural constitution, and the power of imagination and apprehension, its effects may be much greater on some than on others. The common feeling excited by a moderate shock is as if the person received a smart, sudden, but slight blow on the inside of the joints of the elbows and knees. The velocity of the motion of the electric fluid is rapid beyond all computation, and may, in fact, be considered as instantaneous. By experiments made on Blackheath, seven miles east from London, the electric shock was felt at precisely the same instant, although the re-

port was not so loud, by persons at the ends of a circular iron wire above $2\frac{1}{3}$ miles in length. The shock may also be communicated through the ground, however dry it may be, as well as when it is wet; because a very little way below the surface the earth is always sufficiently moist to conduct the electric fluid.

That water is an excellent conductor of electricity has been abundantly proved by repeated experiments. The earliest of this kind was made in London in July 1747. A line of iron wire was laid along the pavement of Westminster Bridge, and turned down the steps at each end to the edge of the Thames. On the Westminster shore stood a person holding the end of the wire in his left hand, and an iron rod dipping in the water in his right. On the Surrey side of the bridge stood another person with the wire in his right hand, and in his left a large coated jar charged with electricity. Near him was a third person who held in his left hand an iron rod dipping in the river, and with his right hand touched the charged jar. The electricity immediately snapped, and the shock was instantaneously felt by the three operators, in the same manner as if the wire had extended without interruption from the beginning to the end of the communication. Hence it was evident, that as the wire was interrupted by the whole breadth of the river, the electricity must have been communicated by the water in the interval between the ends of the wire and rods. The pavement of the bridge measures 1220 feet, which doubled will give 813 yards, or nearly half a mile for the whole length of the communication, one-half of which consisted of the water of the river.

Atmospheric electricity. One of the earliest observations on the nature and effects of electricity was their striking resemblance to those of lightning: and their identity was fully ascertained by the celebrated *Dr. Franklin.* He observed the power of points in drawing off the electric fluid and spark from bodies at a distance, and hence inferred that a pointed metallic bar, if insulated or detached from all electric communication with the earth, by being elevated to a considerable height in the air, would become electric by contact with the clouds, during a thunder-storm. On his suggestion pointed insulated iron bars were erected in various parts of England and France. The first appearance of electricity on any of these bars was on the tenth of May 1752, near Paris. This bar was forty feet high; and it was electrified from the atmosphere for half an hour, emitting sparks nearly two inches long. It occurred afterwards to *Dr. Franklin,* that by means of a common boy's kite, he could have much better access to the regions of thunder than by any rod, or even the loftiest spire. He therefore prepared a kite, and took it into the fields in weather adapted to his purpose. To the lower end of the string was tied a silk cord, to prevent the electricity from passing through his body to the ground; and at the joining was suspended a small key. Several very promising clouds passed over the kite without producing any effect: but just when he was beginning to despair of success, he saw some loose threads of the hempen string standing erect, and separating from one another, just as if they had been suspended on a common conductor of an electric machine. Struck with this appearance, he immediately presented his knuckle to the key, and had the exquisite pleasure to perceive very plainly the electric spark, and to find his opinion of the nature of lightning fully confirmed. Other sparks succeeded, even before the string

was wetted by the rain that fell afterwards; but when it was wet the electricity was collected in great abundance.

The great use to which *Dr. Franklin* conceived his discovery to be applicable was to secure buildings from lightning. This great object is attained by a cheap and apparently inadequate apparatus; merely by a pointed rod of metal reaching higher than any part of the building to which it is attached, and carried down and sunk into the ground, or rather communicating with the nearest water. This rod reaching above the building, and especially being of metal, is sure to be seized upon by the lightning or electricity of the atmosphere, which is thereby conducted down to the earth, without any injury being done to the building. By a similar apparatus applied to the masts, and communicating with the water, ships are equally preserved from lightning.

To have discovered lightning and the electric matter to be the same thing, was a point of great importance; but in both are many appearances still wholly inexplicable. We see that the clouds are almost always electrified, either positively or negatively. When these come near each other, a discharge or flash of lightning takes place; and when a cloud highly charged with electricity comes nearer to the earth than to any other cloud that might attract it, the fluid strikes the ground, passing through, and often destroying buildings, animals, or other objects standing in its way.

To the electric matter are attributed many phenomena often occurring, such as the *aurora borealis*, commonly called the *northern lights*, the *merry dancers*, &c.; balls of fire in the heavens, or shooting stars as they are termed; water-spouts by sea, and whirl-winds by land.—Earthquakes seem, in many cases, to be produced by shocks of electricity; and even in the explosions of volcanoes, lightning or the electric fire is seen darting through the thick clouds of vapour thrown out from the crater. *Animal electricity* is produced by the action of certain organs in living animals, and not by the application of other substances to these animals. The fish tribe alone have hitherto shown themselves to possess this power. Of these are the *torpedo*, the *electric-eel*, and the *electric-silurus*. The torpedo is a flat fish about twenty inches long, common in the seas of Europe. The electric organs are placed on each side of the gills, each consisting of perpendicular columns reaching through the fish. If the torpedo, whilst in the water, or when out of it, but not insulated, be touched with the hand, it gives a tremulous motion or slight shock to that hand alone. If it be touched with both hands at once, the one on the under and the other on the upper side, a shock is felt exactly like that from the electrical jar. The electrical-eel is frequent in the great rivers of South America: its usual length three feet; but some have been described as so large as to strike a man dead by their stroke. Some of these animals three feet long were brought to England forty years ago, and various experiments made with them. They possessed all the properties of the torpedo, but in a superior degree. The spark produced by a shock was visible in a dark room. Of the electric-silurus, an African fish about twenty inches long, too little is yet known to enable us to explain its effects. These animals seem to employ their electrical property as the means of self-defence.

Medical Electricity. This application of electricity may seem to be foreign to the purposes of this work: the reader however will not be dis-

pleased to see a few short observations on a matter of much curiosity, and which may perhaps, in the course of time, produce important benefits to mankind.

In judging of cases of disease or infirmity, in which electrification may be proper, we learn from experience that in general obstructions, whether of motion, of circulation, or of secretion, are often removed or relieved by electricity: the same may be said of nervous disorders. In diseases of long standing, muscular contractions, and the like, electricity is a powerful remedy. In cases of the loss of motion of a limb, it is, however, to be observed, that this loss may be occasioned by the relaxation of one set of muscles, as well as by the contraction of another set. In such cases it will be proper to electrify, not only the contracted muscles, but their antagonists; for to a sound part this will do no harm. Rheumatic disorders of long standing are relieved and frequently cured by only drawing the electric fluid with a metallic point from the part affected, or by drawing sparks into it from the conductor. The operation should be continued for four or five minutes at a time, once or twice every day. When strong shocks are administered, their number should not exceed a dozen, unless they be given to the whole body. In all cases it is proper to begin with the smallest force of electricity, gradually increasing it after some days, if the disease do not appear to yield to the application. Violent tooth-ache is generally cured by an electric discharge made to pass through the tooth and gum affected.

Galvanism and Voltaism. By these terms are meant peculiar appearances and effects resembling and connected with the phenomena of electricity, discovered by *Galvani,* and improved by *Volta,* two ingenious Italian naturalists of the present times. Electricity is excited not only by friction, but by the mere contact of certain bodies. It is necessary, however, that those bodies should have some chemical agency on each other; the effect seeming to be proportionate to the degree of this agency, which therefore is perhaps the cause of the electric phenomena.

It is commonly asserted that porter or beer, and some other liquors, drunk out of a pewter or silver tankard, has a peculiar smartness of taste, very different from the flat taste of the same beer, &c. when drunk out of a glass. Mercury when quite pure retains its metallic lustre a long time; but its amalgam or mixture with any other metal is soon tarnished. When the copper-sheathing of a ship's bottom is fastened with iron nails, the copper, and even the nails themselves will soon be corroded at the place of contact. A piece of zinc or spelter remains a considerable time in water without going to rust or being oxydized: but if a piece of silver be made to touch the zinc in the water, the oxydation takes place very speedily. These different effects are referred to galvanism. If you lay a piece of metal on your tongue, and a piece of some other metal under the tongue; if a connection be formed between the two metals, by bringing their outer edges together, or by touching both with a third piece of another metal, you will perceive on the tongue a peculiar sensation, a kind of irritation, accompanied by a cool acid taste, much resembling that produced by receiving common electricity on the tip of the tongue. If you put a piece of zinc or tin between the upper lip and the gum as high as possible, and a piece of silver on the tongue; whenever the two metals are made to touch one another, or to communicate by means of another piece of metal, a flash

of light will be distinctly perceived in the eyes. The nerves of animals seem to be affected by smaller quantities of electricity than any other substances; hence prepared limbs of animals are much employed for producing electricity by simple contact, or galvanic electricity.

The conductors of electricity are of two classes; the dry or perfect conductors, which are metallic substances and charcoal, and the imperfect conductors, which are water and oxydating fluids (such as corrode or rust metals), and the substances containing those fluids. The most powerful galvanic combinations or circles of the first class are zinc, silver, and water with a little nitric acid, which acts upon both the metals. The most powerful circles of the second class consist of copper with silver or lead, and a solution of an alkaline sulphuret and diluted nitrous acid.

Since Galvani's discoveries the action of the combination of three conductors has been examined with great care and success by various persons, especially by Volta, who discovered that the effect of a single circle or combination may be prodigiously increased by repeating the combination: hence these repetitions of simple combinations are called *Voltaic batteries.*

SECT. VII.

MAGNETISM.

The *magnet* or *lodestone* is an ore of iron of a dark-brown or blackish colour, found in various countries, and from Magnesia, a city in Asia Minor, where it abounded, it derived its name. The great Grecian philosopher, Plato, who died 350 years before the Christian era, in one of his dialogues compares the effect produced by poetry on congenial minds to the operation of the magnet on iron rings, which it not only drew to it, but endowed with a power of attracting other iron rings. Had the ancients, in their magnetic experiments happened to employ long bars instead of circular rings of iron, it is but reasonable to imagine that, on some occasion, when the bars were so placed as to be at liberty to move about, they would have turned, as we see them now do when magnetised, into the direction of the meridian; the one end pointing to the north and the other to the south. Thus would the polarity, as well as the attracting power of a magnet or a magnetised iron bar, have been discovered and rendered available in the purposes of navigation. Whatever may be in this conjecture we have every reason to believe that it was not until many ages after the days of Plato that the polar direction of the magnetised iron bar, rod, or needle came to be known, or at least to be employed in guiding the mariner across the pathless waters. The Chinese, however, assert the use of the magnet in navigation to have been known in their country nearly three thousand years ago: but without observing on the very peculiar na-

ture of the annals of China, it is well known that, even in the presesent times, their seamen are extremely unskilful in the use of the compass, notwithstanding that the magnetic needle they employ seems, from its shortness, to possess some advantages over that used by the nations of the west. The generality of writers on the application of magnetism to navigation attribute its invention, or at least its introduction into Europe, to *Flavio Gioia* of Amalfi, near Naples, about the year 1302; but the mariner's compass is distinctly pointed at in a French poem written a century earlier.

The natural magnet or lode-stone communicates its properties to iron and steel: and pieces of steel prepared and touched by the magnet become artificial magnets. These may be made more powerful than the natural; and as they can be formed in any convenient shape, they are now universally used, while the mineral magnet is only kept as a curiosity. The power of the natural magnets in attracting and supporting a piece of steel in the air, is generally greater in small than in large ones, in proportion to their bulk. One which, including the armature or steel in which it was set, weighed only 43 grains, lifted a piece of steel weighing 1032 grains, just 24 times its own weight. Another very small magnet, worn instead of a diamond (a substance of far less intrinsic value) in a ring, by Sir Isaac Newton, weighed by itself scarcely *three grains*, and yet took up a piece of iron weighing no less than 746 grains, being 250 times its own weight.

All magnets artificial and natural possess the following properties; and without possessing all these properties no substance can be a magnet. 1. The magnet attracts iron. 2. When a magnet is at liberty to move freely, it places its ends pointing towards the north and south poles of the earth: the same end always pointing to the same pole.—This property is the *polarity* of the magnet: and the ends become the *poles*: a magnet in moving about to arrive at this position is said to *traverse*. 3. The north pole of one magnet presented to the south pole of another attracts it: but if the two north poles, or the two south poles be presented to each other, they mutally repel each other. By these means the unknown poles of one magnet are soon discovered, when brought near the known poles of another. 4. When a magnet is free to move in every direction, the axis or imaginary line joining its poles lies horizontally, or inclined in different angles, according to the latitude of the place; that is to say, a magnet, or magnetised iron bar, at the equator, will lie perfectly horizontal or parallel to the axis of the earth; but if it be carried to any place in north latitude, the north end will dip down below the level, and the south end will rise. On the other hand, if the magnet be taken into south latitude the south end will dip, and the north end will rise; and this variation from the level or the *dip*, as it is called, will increase in proportion as the magnet goes nearer and nearer to the respective poles of the earth. 5. Any magnet natural or artificial may, by proper methods, be made to impart those properties to iron or steel. A plane perpendicular to the horizon, and passing through the poles of a magnet in its natural position, is called the magnetic meridian; and the angle formed by this plane, with that of the place where the magnet is situated, is the *declination* of the magnet, otherwise called the *variation* of the magnetic needle.

When a piece of iron is brought within a certain distance of a pole of a magnet it is attracted by it: but this effect is not produced by the

magnet alone, for both bodies equally attract one another. Place the magnet and the iron upon two pieces of cork or wood, floating on water, at a proper distance asunder, and both will move forward till they meet. If the iron be fixed, and the magnet at liberty, it will move to the iron. The attraction is strongest at the poles of the magnet, and diminishes as the iron is placed nearer to the middle point between the poles, where it ceases altogether. The law of the diminution of the attraction is hitherto unknown: it appears, however, to diminish faster than the distance between the magnet and the iron increases. Soft iron readily receives the magnetic properties; but it retains them only a very short time: on the other hand, hard iron, and particularly steel, receives these properties very slowly, but retains them the longer in proportion to its hardness. The powers of the magnet acting upon iron or steel, are not at all affected by the intervention of any other substance between them, except it contain iron. Nor are they affected by the absence more than by the presence of air; but heat weakens them, and cooling restores them, not however to the same degree. A white heat destroys it almost entirely: iron, in a white or a full-red heat, it not attracted by the magnet; but the attraction begins as soon as the redness is going off. The attractive power of the magnet is considerably improved by the application of a piece of iron to it, gradually adding a little more to increase the weight: it is also strengthened by keeping it in a proper position, with its north pole towards the north; and on the contrary, by a wrong position or by having only a small weight of iron, or none at all, suspended from it, its power is diminished. That iron is attracted by the magnet is plain; and it is not improbable that as iron is diffused in various proportions throughout many other substances, it is the cause of their being attracted also, although in a very low degree. Pieces of brass show no attraction for the magnet until hardened by hammering; and when again softened in the fire the attraction goes off, but is a second time restored by hammering. The other metals which possess magnetic properties are *nickel, cobalt,* and *manganese.* Nickel is found chiefly at Freyberg in Germany: it resembles copper-ore; but as no copper could be extracted from it, the miners called it *kupfernickel,* or false copper. This metal is attracted by the magnet as strongly as iron; and like it may be converted into an artificial magnet, in which state it points to the north pole, when freely supported, precisely like the common magnetic needle. An eminent English naturalist, *Mr. Chenevix,* announced a method of obtaining nickel that was not magnetic; but he afterwards discovered that this peculiarity was owing to the presence of *arsenic,* which is commonly found in nickel. For arsenic is not only destructive of all animal life, but it equally destroys the magnetic virtue of iron, and of the other metals in which that virtue exists. Cobalt, a very heavy grey mineral, has been known in Europe for these three centuries past. In 1540 it was first used in Germany to give a deep blue colour to glass, which, when finely pounded, is called *smalt,* a substance sometimes employed in shop-signs, by strewing it on a ground of oil-paint. Smalt is also used in enamels, and in giving a blue tinge to Dutch and other earthen-ware. The finest Dresden china owes its rich blue colour to smalt. Cobalt may also be converted into an artificial magnet, because it generally contains iron from which it cannot be easily separated. Manganese is a dark-grey or brown mi-

neral, very abundant in Derbyshire, in a substance called black wad: it is also found in the greatest purity in the neighbourhood of Exeter. It gives a fine purple tinge to glass, enamels, and earthen-ware; and possessing the seemingly contrary property of purifying glass from any green or yellow tint, it has obtained the name of glass-maker's soap. When manganese, common salt, sulphuric acid (oil of vitriol) and water, are combined in certain proportions, the substance now called *oxy-muriatic acid* is produced, which speedily destroys the colouring matter in linen and cotton-cloth, and is now therefore universally employed in manufactories and bleaching. It was first employed in this way at Glasgow by *Mr. Watt,* afterwards of Birmingham.

It was before noticed that the magnetic meridian varies in many places from the true meridian of the earth; the magnetic north pole, for instance, pointing to the west or to the east of the north pole of the earth; and to account for this fact has hitherto baffled the ingenuity of all enquirers. But this is not all; this variation of the magnetic meridian is itself continually varying at the same place; nor have all the observations hitherto made been sufficient to determine either its rate or its limits. The following table contains a statement of the variation, or declination from the true meridian, of the magnetic needle of the mariner's compass, as observed at London in different years. This table will show that 240 years ago the north pole of the magnet pointed to north by east, or eleven degrees and one-fourth to the east of north: that 160 years ago, it pointed due north; and that moving gradually westward it now points about twenty-four degrees and a half to the west of north, or two degrees to the west of NNW.

Years.	*Variation.*	*Years.*	*Variation.*	*Years.*	*Variation.*
	Easterly.		*Westerly.*		*Westerly.*
	Deg. Min.		Deg. Min.		Deg. Min.
1576	11 . 15	1672	2 . 30	1773	21 . 9
1580	11 . 11	1683	4 . 30	1780	22 . 10
1612	6 . 10	1692	6 . 0	1785	22 . 50
1622	6 . 0	1700	8 . 0	1787	23 . 19
1633	4 . 6	1717	10 . 42	1790	23 . 34
1634	4 . 5	1723	14 . 17	1795	23 . 57
1656	0 . 0	1748	17 . 40	1800	24 . 7
		1760	19 . 12	1802	24 . 6
	Westerly.	1765	20 . 0	1806	24 . 10
1665	1 . 22	1770	20 . 35	1814	24 . 32
1666	1 35				

From this statement it is impossible to form any estimate of the rate of progression in the variation; partly, it is probable, owing to the imperfection of the instruments by which the variation was observed.

For it is only of late years, especially since the introduction of *Macculoch's* improved sea-compass, that the observations requisite for determining the variation of the magnetic needle could be duly performed. The dip or depression of the magnetic needle increasing as it is

carried nearer to the pole of the earth, could it be placed exactly over one of them, it would there stand perpendicular to the horizon: the instrument for showing this depression is the dipping needle.

In giving to iron or steel the magnetic property, various methods are employed, in all of which a magnet is necessary, although in some cases it may seem not to be requisite. Take a bar of iron three or four feet long, and hold it in a perpendicular position; in a little time the bar becomes magnetic, and acts upon another magnet; the lower end attracting the south pole, and the upper the north pole. If the bar be inverted the polarity will be constantly reversed; the end now lowest becoming a north pole, and the upper a south pole. Bars, or any long pieces of iron not very hard, that have stood for some time in a vertical position, generally become magnetical; such as fire irons, window or rail bars. A long piece of hard iron made red hot, and left to cool in the direction of the magnetic line, becomes magnetic: the same effect is also sometimes produced on an iron bar by a stroke of lightning or of electricity. If a slender steel bar or a large needle be fastened on a poker that has stood a considerable time upright, and stroked upwards by the lower end of a pair of tongs, the whole standing vertically, the needle will, after a dozen strokes all upward, become magnetic. The proper methods of magnetising steel bars or needles for the mariner's compass, are nevertheless of such delicacy as to require the greatest attention, in even those who are professionally engaged in the construction of the magnetic needle, and its application in the mariner's compass, of which this is the construction. The compass for ships consists of the box, the card or fly, and the needle. The circumference of the *card* is divided into 32 equal parts called *points*, each containg 11 degrees 15 minutes, and subdivided into quarters. The N. E. S. and W. points are the principal or *cardinal* points of the compass. Thus a point between and equally distant from S. and W. is called SW.; but another in the middle between W. and SW. becomes WSW. while hat in the middle between S. and SW. is called SSW. To the under side of the card, and in the direction of the line joining the N. and S. points is attached a magnetic bar of hardened steel, and of a rectangular form, called the *needle*, by which the N. point of the card is directed towards the N. part of the horizon, and of course all the other points to their corresponding parts of the horizon. The card and needle are placed on an upright pin or *supporter* fixed in the bottom of a brass or wooden circular box; the whole covered with a plate of brass. The box has two pins diametrically opposite, let into a brass ring, moveable in a square wooden box, on two points at right angles to the former. By this contrivance called *jimbals*, the card preserves in general a horizontal position, even when the ship is considerably agitated. When to this compass are added two perpendicular sights, fixed on a brass bar stretched over the box, by means of which the true bearing of the sun or other celestial object may be observed, for the purpose of determining the variation of the magnetic needle, or how much, and in what direction the N. and S. line pointed out by the needle vary from the true meridian of the ship or place of observation. This is called the *azimuth* compass, from an Arabic term expressing the angle formed at the observer's station by the true N. and S. line, and a line drawn to the object observed.

Of the cause of magnetic attraction and repulsion, and of the fluctua-

tion of the direction of a magnetic needle, we are still entirely ignorant. Its variation, however, from the true meridian, the continual change in that variation, and the inclination or dipping of the needle, these and other circumstances seem to indicate the cause to exist in the body of the earth. The celebrated *Dr. Halley* who, above a century ago, in the course of his scientific voyage to St. Helena in the southern ocean, took particular pains to observe the effects of magnetism on the compass, adopted the following ingenious hypothesis. The globe of the earth he supposed to be one great magnet, having four magnetical poles or points of attraction, two near each pole of the earth; and that in the parts of the world adjacent to any one of the magnetic poles, the needle is chiefly governed thereby, the nearest pole being always predominant over the more remote. Of the N. poles, that which is nearest to us the doctor supposed to be situated about seven degrees from the true N. pole, in the meridian of the Land's-end in Cornwall, in W. longitude from Greenwich observatory five degrees forty-two minutes. The other about fifteen degrees from the true N. pole, in a meridian passing over the W. parts of North America, in 120 degrees of W. longitude. The variation of the needle from the true N. and S. points of the world not being uniform, but variable in different years, and in a different manner in various parts of the world, Dr. Halley imagined two of the magnetic poles to be fixed, and the other two to be moveable. To account for this, he conceived the external part of the earth to be a hollow spherical shell, containing within it a magnetic globe, detached from it, but having the same centre of gravity, and revolving round like the earth, but with a motion so small a matter slower as scarcely to become sensible even in a year. Hence would be produced a variation between the true and the magnetic poles, and consequently in the direction of the needle. Different from this fanciful scheme of a most able natural philosopher is that of *Æpinus*, who in 1759 gave it as his opinion, that magnetism was produced by a peculiar fluid, so subtile as to penetrate all substances, and of an elastic nature, its particles mutually repelling one another. Between this fluid and iron, a mutual attraction subsists; but on it no other substance has any action. According to this scheme, a body containing or consisting of iron in its metallic state (not in that of an oxyde or rust) is rendered magnetic by having the equal quantity of fluid diffused through it disturbed, so that it exceeds in one part, and is deficient in another; and its magnetism continues so long as this unequal diffusion lasts, and until the balance between the overcharged and the undercharged parts be restored.

By the following simple experiment the effects of the magnet upon iron may be very perceptible. Strew some iron or steel filings lightly over a sheet of paper on a table, and among them place a small magnet. If by knocking on the table the filings are made to move, they will cling to one another forming lines of different sorts. Those at the two poles arrange themselves in straight lines in the direction of the axis of the magnet: but those on each side begin to bend outward more and more, as they recede from the poles, until at last they form complete arches, meeting together as they bend round from the opposite poles of the magnet. Again, find out by trial a piece of iron a little heavier than can be supported by

a magnet, and apply it to one of the poles. When the hand is removed, the iron must of course drop off; but if before the hand be removed another larger piece of iron be brought within half an inch of the under side of the first piece, the magnet will then be found to support the first piece. Hence it appears that a magnet will support a greater weight of iron over an anvil or other piece of iron, than over a table; for this reason, that the lower iron becoming magnetic in this situation, increases the magnetism of the upper iron, and thereby increases the attraction for, and adherence to the original magnet.

CHAPTER II.

SECT. I.

CHEMISTRY.

THE name of this branch of natural knowledge has been differently written at different epochs. Until within our own days the usual orthography was in English *chymistry,* in French *chymie,* in Latin, Italian, and Spanish, *chymia,* all words derived from *chymos,* a Greek term, signifying *juice, liquor, a fluid.* The present term *chemistry,* may also be formed from the Greek verb *cheo,* or more properly *heo, to pour out;* all significations very applicable to a science which treats of the fusion and liquifaction of solid substances, and of the intermixture of fluid substances.

All natural events consist of one of two things, either of those produced or accompanied by motions perceptible in their progress by our senses, or of those in the progress of which no motions or changes are perceptible by our senses. The first class of objects form *natural,* or more properly *mechanical philosophy;* the second class belong to *chemistry.* Of the several branches of mechanical philosophy, a general notion has been given in the preceding chapter of this work: the present chapter will contain a summary statement of the principles and phenomena of chemistry.

Rise and progress of chemistry. The beginnings of every art, tending either to supply the necessities or to alleviate the inconveniences of human life, were probably coeval with the first establishment of civil society, and preceded by many ages the invention of letters, of hieroglyphics, and of every other mode of transmitting to pos-

terity the memory of past transactions. In vain should we inquire who made the first plough, baked the first bread, formed the first pot, wove the first garment, or hollowed out the first canoe from the trunk of a tree. Whether men were originally left to pick up casual information concerning objects around them, or were supernaturally assisted in the discovery of matters necessary for their well-being, and even for their existence: these are questions which we shall never be able to solve.

It is not to be doubted that, in the period which intervened between the formation of man and the deluge, a great variety of economical arts were carried to a considerable degree of perfection. Of these, however, many must have been lost with the great body of the inhabitants of the earth: for it is scarcely possible that the single and not numerous family which survived the general ruin, had either practised, or even been slightly acquainted with every art in use among the great body of their fellow creatures. Were the inhabitants of the earth to be now swept away by some overpowering calamity, a few persons only being preserved, it will not be difficult to imagine what would be the fate of the various arts by which the elegancies, the comforts, and even the necessities of life are supplied. Centuries might again pass away before the new inhabitants of our globe could become acquainted with the nature and uses of the mariner's compass, with the arts of painting, dyeing, printing, of making porcelain, gun-powder, steel, brass, &c.

Of the events which took place between the creation of man and his destruction by the deluge, the only account on which we can rely is contained in the first six chapters of the book of *Genesis*. In that brief summary of the history of the infancy of society, we cannot reasonably expect to find details, or even the dates of the various useful discoveries in art and science, which were made by men in that period. Short however as is that account, chemists may, not improperly carry, back to the very earliest epochs the antiquity of their art. Tubal Cain is there mentioned as an instructor of every artificer in copper and iron: a proof beyond controversy, that one part of chemistry, that concerned in the management of metals, was then well understood. Copper and iron, it is well known, are with great difficulty extracted from their ores, and cannot, without much skill and trouble, be rendered malleable. Cain, we are informed, built a city; and thence some would infer, that the use of metals was known and familiar, even prior to Tubal.

For many ages after the flood, we have no certain accounts of the state of chemistry. The art of making wine, and the inebriating quality of the juice of the grape, when suffered to ferment, seem to have been unknown to the family preserved in the ark. The Egyptians must have been well skilled in the management of metals, in medical chemistry, and the art of preserving dead bodies, long before the time of Moses, the earliest historian of that singular country, who was born about 1635 years before Christ. This is evident from the account of Joseph's cup, of the embalming of Jacob, &c. Moses also mentions furnaces for working iron, ores from which iron was extracted, and swords, knives, axles, tools for cutting stones, all made of that metal. That the Egyptians at a very early period, understood the art of dyeing and of making coloured glass, appears from history, and from the

relics found with the mummies, or human bodies preserved in the places of sepulture, and from the glass beads with which these bodies are sometimes ornamented. We ought not, however, from any or all of these instances, to conclude that chemistry was studied, either as a branch of science, or in separation from the other useful arts, by the ancient Egyptians. From their knowledge of the art nevertheless some writers are disposed to draw the term chemistry from *kema*, an old Egyptian word signifying the mysteries of nature.

Much speculation has been employed on the fact recorded of Moses, in the book of *Exodus*, (xxxii. 20.) concerning the golden calf or bullock, the symbol of the Egyptian divinity *Apis*. To give the Israelites a practical proof of the absolute inability of the object of their idolatry to confer on them favour or protection, Moses " took the calf which they had made, and burnt it in the fire, and ground it to powder, and strewed it upon the water, and made the children of Israel to drink of it."—Most people have thought that as gold is indestructible in a common fire, the image must have been burnt by some supernatural means. The great German chemist *Stahl*, however, 150 years ago, pointed out a process by which gold might be at least partially dissolved, so as to be rendered potable in water. Sulphur, which readily unites with most of the metals, cannot be combined alone with gold; if, however, the sulphur be united with an equal quantity of a fixed alkali, such as potash or lime, the substance called from its colour liver of sulphur is produced. This substance, if applied to gold in thin plates or leaves, and in the way of fusion, very readily combines with it, or dissolves it. If this compound be immediately poured out of the vessel in which it is melted, and soon after mixed with water, a part of the gold will be dissolved along with the sulphuret, while the rest remains in the state of a very subtile powder. The liquid thus obtained is peculiarly nauseous, possessing an extremely pungent bitterness, not to be found in similar solutions of other metals.

Such is the account of the reduction of the golden calf to powder, in the lectures of the celebrated chemist *Professor Black* of Edinburgh, by which the cavils of the enemies of revelation are completely obviated. It is however observed, in the valuable chemical essays of *Dr. Watson*, Bishop of Landaff, that it is not necessary to suppose that any chemical operation whatever was employed by Moses. The image was stamped and ground down, or (as it is expressed in the *Arabic* and *Syriac* versions of Exodus,) it was filed down to a fine dust, and thrown into the river of which the people used to drink. Part of the gold dust would remain floating on or in the water, and might be swallowed with it in drinking, while the rest would sink down and be carried away by the stream.

Nothing satisfactory can hence be drawn respecting the chemistry of the ancient Egyptians; yet the structure of the ark of the covenant, and the arrangement of Aaron's garments, show the arts of manufacturing metals, of dyeing leather and linen of different colours, of selecting, and engraving on precious stones, were successfully and skilfully practised in the time of Moses, who acquired all his knowledge in Egypt.

Chemistry came in the course of time to be restricted to one branch, and that entirely delusive, of the arts to which it originally extended, namely, to the procuration of gold and silver, by the transmutation or

conversion of the baser metals. To such a pitch was this imaginary art and the belief in its powers carried, at an early period, that the Roman Emperor Dioclesian, of persecuting memory, thought it fit by an edict, in the close of the third century, to repress the ardour for that study in Egypt, ordering all the chemical writings to be burnt, lest by their skill in the procurement of gold, &c. from other substances, the Egyptians should derive the means of throwing off the yoke of Rome.

This limited signification and study of chemistry, greatly prevailed among the ecclesiastics of Greece, from whom it passed to the Arabians, where it was termed *alchymy,* and its professors *alchymists,* by prefixing to the original names the Arabic article *al* or *the;* just as in *alcoran* the title of the Mahometan scriptures, *al* signifies *the* and *koran* or *coran, book.* The alchymists laid it down as a principle, that all metals were composed of the same ingredients, or that the substances composing gold exist in all metals; debased indeed by various impurities, but capable by due purification of being brought to a perfect state. Their great object therefore was to find out the means of producing this change, and consequently of converting the baser metals into gold. The substance which possessed this wonderful and invaluable property, they called *lapis philosophorum,* the philosopher's stone, of which many dishonest, if not infatuated men boasted the possession. Those so highly favoured were styled *adepts,* from the Latin *adepti,* as having obtained possession of the mighty secret. Between the eleventh and the fifteenth centuries, alchymy was in its most flourishing state; but the writings of that period resemble in general rather the ravings of madmen, than the sober investigations of philosophers. In a few, however, may be observed the workings of ingenious minds, reasoning right, but on wrong principles. The efficacy of the philosopher's stone was not confined to the changing of inferior metals into gold. It possessed also the sovereign virtue of curing every sort and degree of disease in an instant, even of prolonging life to an indefinite length, and of conferring on the adepts the gift of immortality on this earth. Not contented with the acquisition of unbounded wealth, and of endless life here to enjoy it, some alchymists turned their thoughts to the discovery of an universal *menstruum,* or substance which would dissolve and reduce to their primary principles all substances to which it was applied. In their eagerness in this pursuit those sages forgot that, when they obtained the object of their labours, it would be impossible to find or to devise a vessel, of any kind, in which this univarsal solvent could be kept for use.

Among the alchymists of the dark ages, we find the names of various persons, qualified by their genius and their industry, in more favourable times, to have made great progress in the study of nature. *Albertus Magnus* (Albert the great) was a German born in 1205. *Roger Bacon,* called Friar Bacon, was a monk of Oxford, born in Somersetshire in 1224. His merits are well known. Some of his writings are extremely obscure; but others exhibit a mind wonderfully enlightened for the age in which he wrote. His tract on the powers of art and nature, would have done honour to his great namesake Lord Bacon. To Roger Bacon, who died in 1292, gun-powder is reasonably aupposed to have been known; although the discovery be commonly attributed to *Berthold Schwartz,* or the Black, a monk in Germany in

1354. So infatuated were the nobility and gentry of England with the pursuits of alchymy, and so much real wealth was exhausted, by artful pretenders, in the vain search of the philosopher's stone, that within a century after the death of Friar Bacon, the interposition of government became indispensable. In 1402, under Henry IV. an act of parliament was passed, (the shortest probably to be found in the statute-book) in these terms: "None from henceforth shall use to magnify gold or silver, or use the craft of multiplication; and if any the same do, he shall incur the pain of felony." This denunciation was, however, no proof of knowledge in either the crown or the parliament. The crown feared the people might, by the manufacture of gold, become too powerful, to continue in due subordination; and the people were apprehensive the crown might acquire so much wealth, as become entirely independent, and consequently arbitrary. This curious prohibition stood unrepealed for nearly a couple of centuries.

The man who first applied chemistry in a regular way to medicine, was *Basil Valentine,* a German monk, born in 1394. To him the world is indebted for the discovery of the virtues of antimonial medicines. Afterwards came *Paracelsus,* born in Switzerland in 1493, who opened at Basil the first public professorship of chemistry in Europe. Notwithstanding his extravagant pretensions, and disorderly conduct, his labours were of service to science and medicine. *Van Helmont,* born in 1577 may be considered as the last of the alchymists: and by his death, in spite of all his skill, a mortal blow was given to the doctrine or dreams of the *panacea* or universal medicine. The foundations of alchymy being thus shaken, its facts remained a mass of confusion, until *Becchcr* appeared.

After suffering many persecutions in Germany, where he was born in 1625, he repaired to England, where he died in 1682. He resided some time in Cornwall, which he called the mineral school, and introduced many improvements into the manner of working mines and fluxing metals; particularly the fusion of tin by the flame of pit-coal instead of wood. This latter fact is however contested; and the use of pit-coal is first dated in the second year of Anne. Beccher's great work, *Physica Subterranea,* was published in Germany in 1669, by *Ernest Stahl,* who adopted his master's system of chemistry, simplifying and improving it so much as to make it entirely his own: it is now accordingly always known by the name of the Stahlian theory.

So early as the year 1645, a number of ingenious and learned persons in London, to divert their thoughts from the horrors of the civil war which then distracted the kingdom, held weekly meetings to treat subjects of what was called the new or experimental philosophy. These meetings were continued in London until 1662, after the restoration of Charles second, when those and other persons were constituted into *the Royal Society.* By the removal of some of the original members to Oxford, similar studies were brought into repute in that celebrated university. Among these last was the Honourable *Robert Boyle,* not less eminent for his talents and knowledge than for the virtuous and useful purposes for the promotion of which they were employed. By his *Sceptical Chemist,* published in 1661, and his other writings and multiplied experiments, he greatly contributed to the introduction of a rational system of chemistry.

Ever since the days of Stahl, chemistry has been cultivated with ar-

dour in Germany, Sweden, and other parts of the north of Europe. Among the philosophers whose names have been illustrated in those countries are reckoned *Margraaf, Bergman, Scheele, Klaproth,* &c. In France, soon after the establishment of the Royal Academy of Sciences of Paris, by Louis XIV. four years after that of the Royal Society of London, *Homberg, Geoffroy,* and *Lemery* gained celebrity by their chemical discoveries. *Rouelle,* who became professor of chemistry in Paris about 1745, infused his own enthusiasm for that study into the whole body of men of science in France. Every where men of skill appeared, discoveries were multiplied, the spirit of chemical research, become fashionable, pervaded the whole nation, spread over Italy, and made considerable progress in Spain.

After the death of Boyle and of some others of the earlier members of the Royal Society, little attention was bestowed on chemistry in Britain, by the generality of men of science. The spirit of mathematical study, infused by the illustrious *Newton,* so predominated for many years, as to absorb the faculties of almost every lover of knowledge. When however *Dr. Cullen* became professor of chemistry in the university of Edinburgh, in 1756, he kindled among his pupils a flame of enthusiasm for that science, which was soon spread far and wide by the subsequent discoveries of *Black, Cavendish, Priestley,* &c. Meeting with kindred fires already burning in Germany, Sweden, France, and other parts of the continent, the science of chemistry burst forth at once with unexampled splendor. In the later volumes of the Transactions of the Royal Societies of London and Edinburgh, of the Royal Irish Academy, of various other less comprehensive philosophical societies distributed over the kingdom, to say nothing of the similar institutions upon the continent, are recorded a multitude of the most important facts, and the most ingenious conjectures, from all which the present state of chemistry, and the names of its most successful cultivators may be satisfactorily learned.

As a branch of science chemistry is intimately connected with all the phenomena of nature. The causes of rain, snow, hail, dew, wind, thunder, earthquakes, volcanos, even the changes of the weather can never be successfully explored by those who are ignorant of chemistry: and the growth of plants, some of the most important functions of animals, have from the same study received all their illustration. No study besides can more powerfully excite in the mind exalted ideas of the wisdom and goodness of the Author of nature than this, which sets before us every where the most astonishing effects produced by the most simple though adequate means, and the peculiar provision made for the well-being and happiness of every living creature. As an art chemistry is also intimately connected with manufactures of every kind. The mason and the bricklayer, the smith and every other worker in metals, the potter, the glass-blower, the tanner, the soap-maker, the bleacher, the dyer, &c. are all really practical chemists; and by the progress of chemistry into all these arts have the most important improvements been introduced. Even agriculture itself can be rationally and certainly understood and promoted, only by calling in the aid of chemistry: in medicine the advantages derived from chemistry are too obvious to require any indication in this place.

Chemical terms. For a long course of years, while chemistry was only a collection of operations in various arts, names were employed

neither properly descriptive nor in any way related. As this study, however, began to assume a form somewhat more orderly and scientific, the improprieties and inconveniences of this practice became notorious, and various attempts were made to remove them. The first of these was made by the celebrated *Bergman* of Sweden, whose arrangement was generally adopted. The study of chemistry being about that time greatly in favour, a number of most important discoveries were made in this country and on the continent, by which new substances and new effects were produced, for which new names were required. Availing themselves of this circumstance, the eminent French chemists *Morveau* in 1781, and *Lavoisier, Berthollet, Fourcroy,* &c. in 1787, published a new system of chemical nomenclature or terms, with a corresponding set of marks or characters. The pretensions of this new language are chiefly these, that by the name and the character of any substance the reader is informed of the several ingredients entering into its composition, and of the relative proportions of these ingredients. Were we perfectly acquainted with the materials composing the substances on which we employ our attention, such a system would be at once most rational and instructive. This, however, is far indeed from being the present situation of chemical science: the most therefore that the French terms can perform is to indicate such ingredients as, in our opinion, constitute each substance. Adopting on many occasions the discoveries of other chemists, in various parts of Europe, (not only without acknowledgment, but often announcing them as their own,) the philosophers before named were persuaded that what they affected to call *French chemistry,* would by this new language establish its superiority over every other system. From the scientific reputation of the inventors, the universality of the French language, and the confident tone in which their doctrines were promulgated, their success was complete: and the French nomenclature is now employed by chemists in all parts of the world. Some facts have however of late years occurred, completely inexplicable by the new system; nay, in certain cases directly in opposition to it: and its claims to philosophic precision and perspicuity begin to be less boldly asserted. *Dr. Pearson* of London published a translation of the French system, which was also commented upon by *Mr. Chenevix,* whose observations and improvements are generally adopted in the popular and excellent *System of Chemistry,* lately published by *Dr. Thomson* of Edinburgh. One of the rules adopted in the French names is to give similar terminations to all substances which agree in their mode of composition, and different terminations to the names of things of different modes of composition. When any acid is in its most perfect powerful or acid state the name ends in English with the syllable *ic,* as sulphuric acid: but when it is in a less powerful or perfect state, the name ends with *ous,* as sulphurous acid. In naming compound salts two words are used, the first signifying the acid, and the second the alkali or base. Thus all compound salts containing sulphuric acid are styled sulphates, as the sulphate of soda, formerly called Glauber's salts: but a compound of sulphurous acid with the same base, will be called the sulphite of soda. In general the names of salts formed by an acid ending in *ic* terminate in *ate,* and those formed by an acid ending in *ous,* terminate in *ite.* The combination of substances with sulphur, phos-

phorus, or charcoal, without any acid, has the name ending in *et*, as sulphur and iron combined become the sulphuret of iron.

As it is not yet thirty years since the new terms were first produced to the world, many of the most valuable works on chemistry, published before that epoch, run the risk of becoming nearly unintelligible by a modern student: it will therefore be useful to give a list of the old and the new corresponding names of the substances most frequently occurring in chemical writings. The terms of the old nomenclature are arranged alphabetically in the first column, and the new terms are placed opposite to them in the second.

Old Names.	*New Names.*
Acetous salts	Acetites
Acid of Alum,—of sulphur,—of vitriol	Sulphuric acid
of vitriol phlogisticated	Sulphurous acid
of nitre phlogisticated	Nitrous acid
of nitre dephlogisticated,—of saltpetre	Nitric acid
of sea salt,—marine	Muriatic acid
aerial,—of chalk,—cretaceous,—of charcoal,—mephitic	Carbonic acid
of spar or fluor	Fluoric acid
of amber	Succinic acid
of apples	Malic acid
of cork	Suberic acid
of galls	Gallic acid
of lemons	Citric acid
of milk	Lactic acid
of sugar	Oxalic acid
sedative	Sebacic acid
of tartar	Tartarous acid
Air	Gas
dephlogisticated,--empyreal, pure,—vital	Oxygen gas
burnt,—impure or vitiated,—phlogisticated	Nitrogen, azotic gas, azote
dephlogisticated marine acid	Oxygenated muriatic acid gas
fixed	Carbonic acid gas
hepatic	Sulphurated hydrogen
inflammable	Hydrogen gas
Alkali caustic	Pure alkali deprived of carbonic acid
effervescent	Alkaline carbonates
fixed	Potash and soda
mineral or marine	Soda
vegetable	Potash
volatile	Ammonia
Alum	Sulphate of alumina
Antimony crude	Sulphuret of antimony
Aquafortis	Nitric acid of the shops
regia	Nitro-muriatic acid

Old Names.	New Names.
Argil, argillaceous earth . . .	Alumina
Black-lead	Carburet of iron
Blue (Prussian)	Prussiate of iron
Butters of the metals	Muriates of the metals
Calces of metals	Oxydes of metals
Ceruse	White oxyde of lead
Chalk	Carbonate of lime
Charcoal, pure	Carbon
Clay, common	Alumina and silica
Copperas, blue	Sulphate of copper
green	iron
Cream of tartar	Tartrite of potash
Earth, aluminous	Alumina
calcareous	Lime
magnesian or muriatic .	Magnesia
ponderous	Barytes
siliceous	Silica
Emetic tartar	Antimoniated tartrite of potash
Essences	Volatile oils
Ethiops martial	Black oxyde of iron
mineral	Black sulphurated oxyde of mercury
Flowers of sulphur	Sublimated sulphur
Heat latent	Caloric
Leys	Solutions of alkalies
Litharge	Vitreous oxyde of lead
Liver of sulphur, alkaline . . .	Sulphuret of potash
calcareous . .	lime
Lunar caustic	Fused nitrate of silver
Magnesia alba, aerated . . .	Carbonate of magnesia
Massicot	Yellow oxyde of lead
Mephitis	Nitrogen
Minium or red lead	Red oxyde of lead
Nitre or saltpetre	Nitrate of potash
Nitres	Nitrates
Oils essential	Volatile oils
fat	Fixed oils
Phlogiston, — principle of inflammability	A principle imagined by *Stahl*, but now rejected
Plumbago, black lead	Carburet of iron
Precipitate, red	Oxyde of mercury by nitric acid
Principle, acidifying	Oxygen
astringent	Gallic acid
tanning	Tan
Pyrites of copper	Sulphuret of copper
martial	iron
Regulus of metals	Metals perfectly pure
Rust of copper,—verdigris . .	Green oxyde of copper
iron	Carbonate of iron
Saffron of Mars, crocus martis .	Oxyde of iron
Sal ammoniac	Muriate of ammonia

Old Names.	*New Names.*
Salt, sea or common	Muriate of soda
Epsom	Sulphate of magnesia
Glauber's	soda
of wormwood	Carbonate of potash
vegetable	Tartrite of potash
Saltpetre	Nitrate of potash
Selenite	Sulphate of lime
Spar, calcareous	Crystallized carbonate of lime
Spirit, ardent	Alcohol
of nitre	Nitric acid
fuming	Nitrous acid
sea-salt	Muriatic acid
sal ammoniac, — harts-horn, — volatile alkali	Ammonia
or oil of vitriol	Sulphuric acid
wine	Alcohol
Sublimate, corrosive	Muriate of mercury
Sugar of lead, or saccharum saturni	Acetite of lead
Tartar	Acid tartrite of potash
emetic	Antimoniated tartrite of potash
vitriolated	Sulphate of potash
Tinctures, spiritous	Resins dissolved in alcohol
Turpeth mineral	Yellow oxyde of mercury
Verdigris, rust of copper	Green oxyde of copper
of the shops	Acetite of copper
distilled	Ditto crystallized
Vermilion, or cinnabar	Sulphurate of mercury
Vinegar, distilled	Acetous acid
concentrated or radical	Acetic acid
Vitriol, blue or roman	Sulphate of copper
green or martial	iron
white	zinc

The operations and implements employed in chemistry are principally these. An *alembic, retort,* or *still,* a vessel capable of resisting heat of various degrees, having a beak or neck projecting from it communicating with another vessel called the *receiver.* The common still is made of copper, and contains the materials to be distilled: it is built up to the neck in brick work; and the fire lighted below is made to run rouud it before it escape. The head of the still is drawn into a pipe or funnel, connected with the worm or spiral tube, immersed in a vessel of cold water called the *refrigeratory,* or cooler. The liquid vapours arising from the materials in the still, in consequence of the heat, are collected in the head, and thence pas into the worm, where they are condensed by the cold in which it is immersed, and from which they issue in a fluid form into vessels placed at its end, to receive the product of the operation which is called *distillation.* Of

this machine a very important improvement was introduced some years ago, under the name of the Scotch still, of which the principal advantages are, that a very increased surface of the fluid in the still is exposed to the action of the fire, and that a very ready method is provided for the escape of the vapour. *Trituration, pulverization,* and *levigation,* express the operations by which solid bodies are reduced into powders of different degrees of fineness, by bruising, beating in a mortar, and grinding on a smooth stone with some liquid. The finer parts of powders are separated from the coarser by the sieve: but sometimes they are washed or mixed with water or other fluid that does not change them: the heavier parts fall to the bottom, and the finer supported in the fluid are poured off with it, which is called *decantation*. *Filtration* is a finer species of sifting or washing, performed through the pores of paper, flannel, fine linen, sand, porous stones, pounded glass, &c. It is of use to separate fluids from solids mixed but not combined with them. Thus muddy water will pass through pure, and leave the mud suspended in it on the filtre: but salt water will not pass through fresh, leaving on the filtre the salt dissolved in it. Unsized or blotting paper answers well for a chemical filtre, when wrapped up like an inverted cone, and placed in a funnel to support it against the weight of the liquid. *Lixiviation* is the separation, by means of water or other fluid, of substances dissolved in it from others not soluble in it. If a substance consisting of salt and clay be broken and placed in water, the salt will be dissolved, and may be poured off from the clay which will remain in the vessel. *Evaporation* is employed to separate a fluid from a solid, or a more volatile fluid from another less volatile. When the vapour is not to be preserved the operation is performed in open vessels capable of bearing heat: but when the vapours are collected and condensed in close vessels the operation is called *distillation*.. When the substances driven off by heat are collected in a solid form within the vessel, it is called *sublimation*. When a salt (that is to say every body possessing a taste, easily melted, soluble in water, and incombustible) is dissolved in any fluid, and the fluid is again thrown off by evaporation, the salt reassumes a solid form, arranging its particles in a particular manner; some as cubes, others as pyramids, others as prisms, &c. Not that each particular salt uniformly assumes one particular form; but that each has a certain number of forms peculiar to itself, in which it is always found. Thus common salt always forms itself into a cube or solid of six sides, into an octohedron or solid of eight sides, or into some other figure reducible to one of these. This process is termed *crystallization*. *Solution* expresses the effect produced on certain solid substances when acted on by fluids. When salt or sugar is mixed with water, or when resin is mixed with spirits of wine, the particles of the solid are separated from each other, and intimately united with the fluid. Each substance, however, retains its original properties, and by evaporation the salt, &c. may be restored to its original solid state, and in its original quantity. When the fluid has dissolved as much of the solid as it can, it is said to be *saturated*, and if more of the solid be added it will remain undissolved. But in the dissolution of metals by acids a different effect is produced: for then either the metal or the acid, or the water in it is altered, and new products are obtained. The liquid used to dissolve a solid, is called a *menstruum* or *solvent*. If to a solution of a solid in a fluid a third substance be added, which has

a stronger affinity for the fluid than the first body, it will unite with it, and the dissolved solid will be thrown down, restored to its original solid state. This operation is called *precipitation.* For instance, common salt thrown into pure water is dissolved and dispersed through the whole water; if however a quantity of spirit of wine be poured into the solution, the salt becomes visible, detaches itself from the water, and is precipitated to the bottom of the vessel, in the state of a very fine powder. The affinity or attraction of the particles of the water for those of the spirit of wine being stronger than that for the salt, the salt is abandoned by the water, which hastens to unite with the spirit. When any body is made, by the action of heat, to pass from a solid to a liquid state, it is said to be *fused* or *melted:* but this last term is not so proper, because simple solution is also commonly called melting: fusion is therefore usually employed in chemistry. Metals are fused in *crucibles,* small open vessels of earthen ware or porcelane, or of a mixture of clay and black-lead in powder. For very delicate operations small crucibles have also been made of *platinum* the densest of all known metals. When broad and shallow they are called *cupels,* and the arched cover or *muffle* over them admits the air to the metal. The various degrees of heat required for chemical operations, from that of a wax taper, to that of the most intense fire, require a variety of fire-places or furnaces, distinguished by different names descriptive of their nature or uses. *Blow-pipes* are employed to direct the flame of a taper or lamp by the breath, against a bit of ore or other substance to be examined.

When a body is burned, with the assistance of the air we breathe, it is said to be in *combustion:* but when the burning is attended by slight explosions or cracklings it is called *deflagration;* and when the explosion produces a loud report it is *detonation.*

First Of simple or elementary substances.

It was an opinion established among philosophers of ancient times (and the expression of it is not yet banished from common language), that there were only four simple substances, namely, *earth, water, air,* and *fire.* These they called *elements,* as supposing all other bodies to be composed of them. We now know, however, that all these supposed first elements are themselves compounds of others. *Earths* may be separated into nine different kinds of substances, by the union of two or more of which every kind of earth is formed. *Water* is a compound of two principles, called *hydrogen,* because it produces water, and *oxygen,* the cause of acidity. *Air* consists of oxygen and azotic gases. Fire is composed of light and caloric, or the principle of heat. The alchymists however classed all bodies under *salt, sulphur,* and *mercury,* without probably affixing any precise meaning to the terms. For every thing which resisted fire they called salt; whatever was consumed by fire they called sulphur, and every substance that flew off without burning was called mercury.

By simple substances at the present day, we mean only such as have not yet been de-compounded, or which we have yet no reason to suspect to be compounds. The simple substances now known are reckoned to be 32, divided into those that can be confined in proper vessels,

and those that are of a nature too subtile to be confined within any vessels we possess.

Division First.

The *confinable* substances are in number 29, arranged under 4 heads; viz. 1. oxygen, 2. simple combustibles, 3. simple incombustibles, and 4. metals.

I. The first class comprehends only one substance called oxygen, of a very peculiar and important nature. The common air consists chiefly of two fluids, one of which supports animal life, and in it metals are calcined or oxydized, and combustibles burn. The other fluid possesses the directly opposite qualities. The base of the first is *oxygen,* so called from two Greek words signifying to produce acidity, because one of the most general properties of this base is to form acids when combined with certain other substances. When oxygen is united with the principle of heat, it forms oxygen gas, which was formerly called vital or pure air. It is elastic and invisible, and gives no signs of acidity. It is 740 times lighter than an equal bulk of water: but heavier than common air, as 1103 to 1000. It is not sensibly absorbed by water; but entirely so by bodies in combustion. It is necessary for breathing, and the support of life.

Oxygen may be procured from various substances, even from the green leaves of plants, although in a small quantity. For this purpose fill a bell-glass with water; introduce fresh green leaves under it, when inverted in a vessel also containing water. If the apparatus be exposed to the sun's rays pure oxygen gas will be disengaged, and ascend through the water to occupy a part of its place in the upper part of the bell-glass. The most common way however of obtaining oxygen gas is from the black oxyde of manganese, (the state in which this mineral is commonly found) reduced to a powder, and heated in a stone or iron retort. When the retort is red-hot, the oxygen is plentifully obtained, and may be received into an inverted vessel filled with water, which the gas will displace. One pound of good manganese yields upwards of 1400 cubic inches of oxygen gas nearly pure. If sulphuric acid (oil of vitriol) be added to the manganese, the gas is produced in a larger quantity, and in a lower heat; so that a glass retort may be used, and the heat of a lamp is sufficient.

If a lighted taper be let down into a phial filled with oxygen gas, it will burn with such splendor, that the eye can scarcely bear the glare of the light, producing also a much greater heat than when burning in common air. Animals live much longer in oxygen gas than in an equal quantity of the common air of the atmosphere, of which indeed that gas forms nearly one-fourth part.

Gas. This term now so common on matters relating to chemistry is nevertheless no novelty in the science. It was employed, two hundred years ago, by the last of the alchymists Van Helmont, formerly mentioned, to express the vapour which escaped from liquors during the vinous fermentation, and indeed every thing driven off from bodies in a state of vapour, by heat. By gas at present is understood a fluid perfectly invisible, and elastic, that can be contained in a vessel, that expands by heat, and contracts by cold, but is never condensed into a liquid or solid, as the vapours of water or camphor.

II. The second class of simple substances, are the simple combustibles, which are four in number, viz. sulphur, phosphorus, carbon, and hydrogen.

1. *Sulphur*, or brimstone, (a corruption of burnt-stone) was known in the earliest ages; and being found native in many parts of the world, it must soon have attracted attention. It was used by the ancients in medicine, and its fumes or vapours were employed to bleach wool. It is a non-conductor of electricity, and therefore becomes electric by friction. Sulphur is generally found in the neighbourhood of volcanos, either burning or extinct, as a loose powder. At the *Solfatara*, the bason of an extinct volcano near Naples, the sulphurous vapours ascend through cracks in the ground, and are collected on stones placed round them, to be afterwards dissolved and crystallized. Sulphur is also found in mineral waters, as in the springs at Harrowgate in Yorkshire. The yellow brassy cubes often seen in slates are composed of sulphur and iron or copper, and called pyrites. This substance is exposed to heat in earthen tubes connected with a vessel of cast iron containing water. The sulphur as it melts is collected in the water, after which it is again melted and poured into moulds, whence it comes out as roll-sulphur. This being sublimated by gentle heat in a close room, the vapours are collected in what is called the flowers of sulphur. With most of the metals sulphur unites, rendering them brittle and fusible. If a bar of iron be made red-hot, and then touched with a roll of sulphur, the two combine and drop down together in a fluid state, forming sulphuret of iron, of the same nature with the native iron pyrites. Put some threads moistened and dipped in sulphur into a vessel floating on water; set them on fire, and cover the whole with an inverted glass. The threads will burn some time, and the glass will be filled with dense white vapours. The water will ascend into the glass, and after some time the vapour will disappear. The water combining with it acquires a suffocating smell and taste, turns blue vegetable colours to red, and gives all other marks of the existence of an acid: this is the sulphurous acid. Again, take any round bottle with a wide mouth, containing some water; fit to it a cork to which is fixed an iron spoon containing a mixture of one part of nitrate of potash, (saltpetre,) and six of sulphur; set the mixture on fire, and introduce the spoon quickly into the bottle, corking it very tightly. The combustion will go on rapidly, and the water in the bottom of the bottle will become sour; but without much suffocating odour. This is sulphuric acid, commonly called oil of vitriol, or vitriolic acid, because it was usually obtained by distilling green vitriol, a salt composed of sulphuric acid and the green oxyde or calx of iron.

Acids. This term signifying originally *sour*, has been extended to all substances possessing these properties. 1. When applied to the tongue they excite the sensation of sour, in Latin acid. 2. They change the blue colours of vegetables to red. The blues usually employed for this purpose are the tincture of litmus, and the syrup of violets or radishes. 3. They unite with water in almost any proportion. 4. They combine with all the alkalies, and most of the metallic oxydes and earths, forming the compounds which we call in general salts. It is to be observed, however, that every acid does not possess all those properties; but all possess so many of them as to distinguish them from

other substances. The acids are by far the most important class of bodies in chemistry.

Alkalies. These are just the reverse of the acids. The word is Arabic, formed from observation of the properties of the plant *kali.* When it is burnt, and the ashes are washed in water, and afterwards evaporated to dryness, a white substance remains, to which was given the name alkali. The term is now however extended to all substances possessing the following properties. 1. A caustic, that is a burning taste. 2. They are volatilized by heat. 3. They are capable of combining with acids. 4. Soluble in water even when combined with carbonic acid. 5. Capable of converting vegetable blues to green.

The alkalies at present known are potass, soda, and ammonia, of which in their proper place.

2. *Phosphorus,* so called from Greek words signifying the bearer of light, is never found pure in a natural state, but commonly united to oxygen, under the form of phosphoric acid, in different substances, animal vegetable and mineral. Phosphorus is usually yellowish and partially transparent, of the consistence of wax. At the common heat of the atmosphere it gives out light in the dark; taking fire spontaneously, and burning rapidly in the open air, when heated to 122° of Fahrenheit, with a brilliant white flame; and is then changed into phosphoric acid. Phosphorus, was originally and accidentally discovered by *Brandt,* a chemist of Hamburgh, in 1669, in labouring to extract from urine a liquid which he hoped would turn silver into gold. It is now procured by a very different process, namely, from a combination of burnt bones, sulphuric acid, sugar (acetate) of lead, and powdered charcoal. Near Bolognia in Italy is found a stone or rather heavy spar, which after exposure to the sun's rays retains for a considerable time the property of giving out light.

3. *Carbon.* If a piece of wood be put into a crucible, well covered with sand, to exclude the air, and kept red-hot for some time, it is converted into a black shining brittle substance, without taste or smell, well known under the name of charcoal. Its properties are the same from whatever wood it be obtained, provided it be exposed for an hour, in a covered crucible, to the heat of a forge. Unless this precaution be used, the properties of charcoal differ considerably. Common charcoal prepared by slowly burning a pile of wood, covered over with earth to exclude all external air, is not quite pure; but it may be purified by washing it repeatedly when powdered in water, and then drying it in a strong heat in a close vessel. Charcoal is insoluble in water, and never will putrify or rot like wood. It is for this reason that the ends of stakes and posts intended to be planted in the ground are partially burnt or charred; a practice well known to antiquity. In the year 1776, operations were carried on by the Neapolitan government, for clearing the entrance of the once famous harbour of *Brundusium,* now *Brindisi,* toward the south-east extremity of Italy. In removing the sand and mud, to deepen the water, were found some hundreds of long stakes or piles, of which the lower ends had evidently been charred, and which from their position and arrangement, from coins found among them, and from other circumstances, must then have been in that situation for eighteen hundred and twenty-four years. For they were undoubtedly, parts of the moles constructed in the year 48, before the christian era, by *Julius Cæsar,* in the beginning of the civil wars of

Rome, in the view of preventing the escape by sea of his insatiably ambitious and unrelenting enemy *Pompey*.

Charcoal forms a considerable proportion of all animals and vegetables. When new made, and wrapt up in clothes that have contracted a disagreeable odour, it effectually destroys it; when boiled with meat beginning to putrify, it takes away the taint: and it is perhaps the best of all substances for a tooth-powder.

Charcoal is composed of two substances, the one which is its essential and characteristic ingredient, and therefore called *carbon*, (from the Latin term for charcoal or wood-fuel,) and oxygen, already described. Nothing can appear to be a more direct contradiction, not in terms only but in fact, than the assertion that charcoal and the most precious of all stones, the *diamond*, are one and the same substance. When pure the diamond is perfectly transparent and peculiarly brilliant. Its figure is various, but most commonly it is found in the form of a prism of six sides, terminated by pyramids of six sides. It is the hardest of all bodies: the best tempered steel makes no impression on it; and only by grinding it with another diamond, whole or in powder, can it be affected. The weight of diamond is to that of pure water, as $3\frac{1}{2}$ to 1. As the diamond is not affected by a considerable heat, it was for many ages considered to be incombustible. To the transcendent genius of Newton it was reserved to conceive that the diamond, like many other bodies, was also combustible. Observing that combustibles refract light more powerfully, in proportion to their density, than other bodies, (see *Optics*,) and that the diamond possessed the refracting property in great perfection, he judged it then to be susceptible of combustion. This singular conjecture was first verified before the grand duke of Tuscany in 1694, by means of a powerful burning-glass. Similar experiments were afterwards made in other parts of the continent, and latterly in this country. Before a diamond can be burnt it must be exposed to the sun's rays collected in the focus of a large burning-glass, or to a heat of fourteen or fifteen degrees of Wedgewood's scale. The product of the combustion is carbonic acid gas, of which 100 parts contain nearly 18 of diamond and 82 of oxygen, and 100 parts of charcoal contain nearly 64 of diamond and 36 of oxygen. Iron exposed to a strong heat in combination with charcoal is converted into steel: the same effect is produced in iron heated with diamond.

From the experiments here mentioned it appears that the French chemists Lavoisier, &c. mistook the nature of carbon, which exists pure only in diamond; whereas charcoal is not carbon alone, but carbon and oxygen, and should therefore, according to their own doctrine, be called an oxyde of carbon.

4. *Hydrogen* is the last of the simple combustible bodies. It is obtained in the form of gas, by pouring sulphuric acid, diluted with double its bulk of water, upon iron filings in a retort; the vapour arising from these substances is hydrogen gas, formerly called *inflammable air*. This gas is found abundantly in nature, in coal-mines, where it is called the *fire-damp*, because it instantly extinguishes fire; also in muddy and marshy waters, and in all places where animal or vegetable substances are in the progress of putrefaction. When greatly diluted with common air, hydrogen gas may be breathed without much danger; but when pure it is speedily destructive of animal life. If a vessel be filled with it, and a candle or a red-hot iron be brought to the mouth, the

gas takes fire and is wholly consumed. Hydrogen gas and pure oxygen mixed together in a vessel continue unaltered: but if a lighted taper touch them, or an electric spark, they burn with astonishing rapidity, and explode with violence. If 85 parts by weight of oxygen gas, and 15 of hydrogen gas be mixed in a close vessel, and made to explode, both completely disappear, and in their room in the vessel is found a quantity of water, exactly equal in weight to them both. By this fact we are taught, that water is not a simple substance, but a compound of oxygen and hydrogen, which last has hence its name, which in the Greek signifies what produces water. It has been with much probability conjectured that detonations in the air, or what we call claps of thunder, are produced by the rapid combustion of oxygen and hydrogen gases, fired by electric matter, or what we call lightning; and that the rain which descends so copiously during thunder-storms is the water suddenly formed by the combustion. Hydrogen gas is the lightest substance of which we are able to measure the weight, being about twelve times lighter than common air; and for this reason it is employed to fill air-balloons. It dissolves sulphur, phosphorus, and carbon, forming therewith sulphureted, phosphureted, and carbureted hydrogen gases. The first compound was formerly called hepatic gas: it has a highly fœtid odour, similar to that of rotten eggs, which is in fact owing to the emission of this gas; it also gives the strong odour to Harrowgate waters.

All the simple combustible bodies may be combined with one another; and to the combinations are given names ending in *uret*, and derived from the ingredient which characterizes the compound. Thus we have the carburet of sulphur, and the sulphuret of carbon; in the first the carbon predominating, and in the last the sulphur.

III. The third class of simple confinable substances are the simple incombustibles, which are only two, vix. azote and muriatic acid. Several other incombustible bodies, not hitherto de-compounded are known; but there is reason to suspect them not to be simple bodies.

1. *Azote.* If iron filings and sulphur mixed together be moistened with water, and put into a glass vessel full of common air, the oxygen of the air will be entirely absorbed in the course of some days; but a considerable portion of air will remain, incapable of any farther diminution. This remaining portion of the air is azotic gas. The same product is obtained much more speedily by applying a heat of 100° to very weak nitrous acid (aquafortis) poured upon a piece of muscular flesh. This gas, which was first discovered in 1772 by *Dr. Rutherford,* professor of botany in Edinburgh, is very nearly as heavy as common air, and like it may be condensed or expanded. It is exceedingly noxious to animals, which, if obliged to breathe it, expire immediately. From this property it has its name drawn from Greek words signifying what is destructive of life; an appellation not however belonging to this gas alone; for we have just seen that hydrogen gas is almost as suddenly destructive of animal life.

If 13 parts of azotic gas, and 87 of oxygen gas, be introduced into a tube deprived of air, and a number of electric sparks be sent through the mixture, the gases disappear, and in their place is found a small quantity of nitric acid. But it is usually procured by distilling three parts of nitre (saltpetre,) and one of sulphuric acid, in a glass retort. The nitrous acid is generally obtained, in large manufactories, by

distilling a mixture of nitre and clay: but in this case the acid or aquafortis is always weak and impure. When azotic and hydrogen gases are combined together by heat the compound is ammonia, or the volatile alkali, called also spirit of hartshorn, or of sal ammoniac, from the substances from which it is drawn.

2. *Muriatic acid,* so called from the Latin *muria,* expressing the saltness of the sea, is also known as acid of salt, and marine acid. It is obtained from the mixture of equal quantities of common salt and sulphuric acid. By the application of heat a violent effervescence or boiling takes place, and a vapour is produced called muriatic acid gas. This fluid resembles common air, in its mechanical properties, but is nearly twice as heavy, and hence may be poured from one vessel into another like water. Its smell is pungent and peculiar; and when in contact with air a visible white smoke is produced. When drawn into the mouth the taste is excessively acid; much more so than the sharpest vinegar. No animal can breathe this gas, and when thrown into a jar filled with it they die instantaneously: neither will any combustible burn in it. When combined with earths, alkalies and metals, it forms muriates. The compound of the muriatic acid with soda, or the muriate of soda, is the common *sea-salt,* sometimes called sal gem. Common salt exists native in great abundance. Immense masses of it are found in various countries, requiring only to be dug out and reduced to powder. In this state it is called rock-salt. The water of the ocean also contains a great proportion of this salt, to which it owes its taste, and its power of resisting freezing, till cooled down to $28\frac{1}{2}°$ or $3\frac{1}{2}°$ below the freezing point of fresh water. When sea or salt water is evaporated by heat, the salt falls down in crystals; in this way is salt obtained in this country. But this salt is not sufficiently pure for chemical purposes, as it contains in general a compound of muriatic acid with lime, magnesia, &c. According to late experiments, purified salt contains, in 100 parts, 39 of acid, 53 of soda, and 8 of water. If a plate of iron be kept for some days in a solution of salt in water, it will separate the soda from the acid, which will form a crust on the iron.

Salt assists the fusion of glass, and causes clay to fuse readily, for which reason it is employed in glazing earthen ware. If a little of the blue liquid obtained by boiling red cabbage leaves in water in a tin vessel, be let up into a vessel of muriatic acid gas, the gas is absorbed, but the liquid assumes a fine red colour. This property of changing blue vegetable colours to red is characteristic of acids in general.

If manganese be put into a glass retort with muriatic acid, and exposed to heat, strong fermentation will be excited, during which the acid is converted into gas, but surcharged with oxygen drawn from the manganese. In preparing this gas great care must be taken to prevent its escape into the apartment. The French chemist *Pelletier* fell a sacrifice to an attempt to breathe it; for a consumption was brought on which soon proved mortal. The use of this oxygenated muriatic acid, or as it is called oxy-muriatic acid, is of great importance in *bleaching:* for instead of turning blue vegetable colours to red, it destroys all colours entirely, and is therefore of great service in whitening thread, linen, cotton, wax, &c.

IV. The fourth class of confinable bodies comprehends the metals. These are the great instruments of all our improvements: without them few arts and sciences would have existed. So sensible were the ancients

of their great importance, that they exalted to the rank of deities those persons who first discovered the art of working them. In chemistry they have always filled a conspicuous station: at one period the whole science was confined to them; and to the rage for making and transmuting metals, chemistry may be said to owe its very existence.

The distinguishing properties of metals are these. 1. Lustre or brilliancy, for which reason they always form the basis of reflecting mirrors. 2. Opacity, or impenetrability to light, another requisite for mirrors. 3. They may be fused and still retain their opacity, which qualifies them to be cast in moulds and shaped as we choose: but in their fusibility they greatly differ; for mercury continues fluid in the ordinary heat of the atmosphere, while platinum can be fused only by the most violent possible heat. 4. Their specific gravity is much greater than that of any other class of known bodies. Antimony, one of the lighest of the metals, is more than six times as heavy as water; and platinum the heaviest of them all is twenty-three times as heavy as water. This great density of their particles contributes greatly to the reflection of a great quantity of light, constituting the metallic lustre. 5. Metals are the best conductors of electricity. 6. None of them are very hard; but some of them may be hardened by art to such a degree as to exceed in hardness almost all other bodies. 7. The elasticity of the metals depends upon their hardness; and it is increased by the same process which increases their hardness. 8. One of the most important properties of the metals is their malleability, or their capacity of being extended, flattened, and shaped, when struck with a hammer. This invaluable property is not common to them all however: but it is remarkable that almost all those possess it which were known to the ancients. This property is increased considerably by heat: but metals become denser and harder by being hammered. 9. Another property not common to all metals is ductility, or the capacity of being drawn out into wire, by being forced through holes of various diameters. 10. Ductility depends, in some measure, on another property, namely, tenacity, or the power which a metallic wire of a given diameter possesses, of resisting, without breaking, the action of a weight suspended from its extremity, or of being strongly pulled in opposite directions. This tenacity is very different in different metals. A wire of iron, for instance, one-tenth of an inch in diameter, will bear without breaking nearly 500 pound weight; whereas a wire of lead of the same size will not bear above 29 pound. 11. When exposed to the action of heat and air together, most of the metals lose their lustre, and are *calcined*, or converted into earthy-like powders of different colours and properties, according to the metal and the degree of heat employed. Several even take fire when exposed to a strong heat, and after combustion the remainder is found to be the very same earthy-like substance. 12. If any of these remaining substances or *calces*, (as they are called, from the Latin term for ashes, also lime or chalk in dust or powdered) be mixed with charcoal in powder, and exposed to a strong heat, in a proper vessel, they are again converted back to the metals from which they were produced; or they are said to be *reduced*, and the operation is termed *reduction*.

From these facts *Stahl* conceived that metals were composed of earth and *phlogiston*, a Greek name signifying whatever is capable of combustion, of which a certain portion exists in all combustible bodies. Several phenomena however of the calcination of metals remained still

unexplained, particularly this, that the calces of metals are all considerably heavier than the metals from which they are obtained. At last in the *memoires* of the Academy of Sciences of Paris for 1774, appeared an account of the experiments of the eminent chemist *Lavoisier*, by which it appeared that a certain quantity of air disappeared in calcining a piece of metal, which was precisely equal to the excess in weight of the calx above the original metal. By the subsequent discoveries of our most ingenious countryman *Dr. Priestley*, it was ascertained that only one of the component parts of air disappeared during calcination, namely the oxygen or principle of acidity; and that the weight of the oxygen being subtracted from that of the calx, the remainder was always precisely equal to that of the metal before calcination. Calcination is therefore the union of a metal with oxygen: and if any substance having a greater affinity with oxygen than the calx, as charcoal for instance, be combined with the calx, the oxygen will leave it to unite with the charcoal, and the calx will return to its original metallic form, weight and properties. In consequence of these facts the terms calx and calcination have been laid aside, as conveying false ideas; instead of which *oxyde*, and *oxydisement* are now adopted in chemistry. We are now brought to the 13th property of metals, which is that they are all susceptible of combination with oxygen, sometimes accompanied by combustion, and sometimes not. The new compounds are called *metallic oxydes*, and in some cases *metallic acids*. According to the proportion of oxygen the oxydes acquire different properties and colours: but the colour ought never to be taken as a sure mark of the quantity of oxygen in the compound; for that depends on various other circumstances. 14. Metals are capable of combination with simple combustible bodies: and the compound is denoted by the name of the combustible ending in *uret*. Thus the combination of a metal, as silver with sulphur or phosphorus, is called the *sulphuret* or the *phosphuret* of silver. 15. Lastly the metals are capable of being combined with one another, and of so forming mixt substances, some of them of the greatest utility in the manufacture of instruments and utensils. Thus lead and tin together form pewter; copper and zinc, formerly called spelter, make brass; copper and tin, in different proportions, form bell-metal, bronze, cannon, mirrors for telescopes, &c. All these metallic compounds are called *alloys*, excepting when mercury is one of the ingredients, when the compound is called an *amalgam*. Thus the gold coin of this country is a mixture of eleven parts of gold with one of copper, by which the gold is alloyed, that is allayed or lowered in purity. But a mixture of gold with mercury is an amalgam of gold.

THE METALS.

The metals at present known amount to twenty-three, of which only eleven were distinguished before the year 1730. They may be arranged under three classes, viz. 1. Malleable metals. 2. Such metals as are brittle, and easily fusible. And, 3. Such as are brittle but fused with difficulty. The metals belonging to each class are shewn in the following table.

I. *Malleable.*

1. Platinum	6. Iron
2. Gold	7. Tin
3. Silver	8. Lead
4. Mercury	9. Nickel
5. Copper	10. Zinc

II. *Brittle and easily fused.*

1. Bismuth	3. Tellurium
2. Antimony	4. Arsenic.

III. *Brittle and difficultly fused.*

1. Cobalt	6. Titanium
2. Manganese	7. Chromium
3. Tungsten	8. Columbium
4. Molybdenum	9. Tantalium
5. Uranium	

The metals of the 1st class were formerly called *metals,* by way of excellence, as being either malleable or ductile, or both: all the others were called *semimetals* (half metals), because they possessed none of those properties. The first four were also called *noble* or *perfect metals,* and the next four were called *imperfect.* Those distinctions conveying very improper conceptions of the metals, are now laid aside.

1. *Platinum.* This metal was unknown as a distinct metal in Europe before the year 1752. It has hitherto been found in South America alone, at Choco in Peru, and at Santa Fe, near Carthagena, on the north coast. The substance was however first brought to England by *Mr. Wood* from Jamaica in 1741. Seven years afterwards it was noticed by *Ulloa,* one of the scientific men employed in Peru, in measuring a degree of the meridian under the equator. It was *Scheffer* of Sweden, who in 1752 proved it to be a distinct and a new metal.

Platinum when pure is white like silver, but not so bright, and verging to tin; has no taste nor smell; its specific gravity when hammered is twenty-three times that of an equal bulk of pure water, so that it is by far the heaviest body known; it is exceedingly malleable and ductile, and may be hammered out into very thin plates. In these properties however platinum is perhaps inferior to gold; but all other metals it surpasses. Such is its tenacity, that a wire made of it one twelfth of an inch in diameter will support a weight of 275 pounds avoirdupois. Platinum was at first called platina, as derived from *plata,* the Spanish term for silver, from which we have our *plate,* to signify vessels of silver, and *plating,* for covering inferior metals with silver. It is found in small grains, and always in a metallic state; it is the most infusible of all metals; for it cannot be melted, in any useful quantity by the most powerful artificial heat that can be produced. When combined or mixed with some other bodies it may be melted without diffi-

culty; but then it is no longer pure. In 1788, when the art of melting, casting und polishing platinum was known in Spain, the late king *Charles the Third* (grandfather of the present Ferdinand the 7th) transmitted to the late liberal Pope *Pius the Sixth* two communion-cups, to be used in high ceremonies in St. Peter's church in Rome, as the first fruits of the new and singularly precious metal, the production of his American dominions. As platinum is not acted upon by the most violent heat, nor by air or water, nor by any other than the nitro-muriatic acid, (aqua regia), by boiling the metal in sixteen times its weight of the acid, it might be of the utmost utility for vessels, were it to be obtained at a cheap rate: indeed, as it is, small crucibles, scales, and other implements are made of it, for performing very delicate operations in chemistry, geometry, &c.

2. *Gold* seems to have been known and valued from the very beginning of the world: it has hitherto been found only in a metallic state, in grains, ramifications and leaves. No metal perhaps excepting iron is more widely scattered over the globe; but generally in very small quantities. There are few countries in which gold grains are not found in the sands of mountain-torrents and rivers. Spain in ancient times furnished Europe with gold: but since the discovery of the American treasures, the Spanish mines have been closed up. From the mines of Hungary the Emperor of Austria draws very considerable sums.

No substance is comparable to gold for ductility and malleability; for it may be beaten out into leaves so thin, that one grain of gold (480 in 1 ounce) will cover a square of $7\frac{3}{5}$ inches a side, or $56\frac{3}{4}$ square inches. These leaves can be in thickness no more than a two hundred and eighty two thousandth part of an inch, so that 282 thousand of them would only make an inch in thickness. But the gold leaf with which silver wire is covered, is reduced so low as to be only one twelfth part of the former thickness. An ounce of gold upon silver wire may be drawn out to an extent of above thirteen hundred miles. Notwithstanding this prodigious closeness of parts, gold yields in tenacity to iron, copper, platinum and silver; for a gold wire one-twelfth of an inch in diameter bears only about 150 pounds weight. When melted gold assumes a bright bluish green colour, and expands considerably, contracting again when cold, so that it is not proper for casting in moulds. Gold is not the least altered by exposure to the air or water; it will also bear to be kept red-hot for a great length of time, without undergoing any change. It is however capable of combination with oxygen, and even of combustion in certain circumstances. The result is an oxyde of gold, which is of two kinds, purple or violet when the quantity of oxygen is small; but yellow when it is large. When exposed to the violent heat of a very powerful burning-glass, or when an electric spark is sent through gold, it forms the purple oxyde. Gold is acted upon by no acid but the nitro-muriatic or aqua regia, so called because gold was formerly called the king of the metals. This solution of gold yields by evaporation crystals of a beautiful yellow colour, which when dissolved tinge the skin of an indelible deep purple. If into this liquor be dropped a solution of tin in muriatic acid, the gold is thrown down in a fine purple powder, well known under the name of the precipitate of Cassius, much employed in porcelain and enamel. Gold has not yet been combined with sulphur, carbon or hydrogen; nor with the simple incombustibles. It

unites readily however with the greater number of the metals, forming a variety of alloys.

3. *Silver.* This metal seems to have been known almost as early as gold. It is inferior in brilliancy to no metal but perhaps steel when finely polished: in malleability it stands next to platinum and gold. It may be beaten into leaves into a one hundred and sixtieth part of an inch thick, and may be drawn into wire finer than any human hair, so that a single grain may be extended about 400 feet in length. A wire of silver one-twelfth of an inch in diameter will support a weight of 187 pounds. Silver melts when it becomes completely red-hot; and its brilliancy is then much increased. If the heat be increased after it is melted the liquid boils; and by a very strong and long continued heat it may be volatilized. Silver is not oxydized, (rusted) by exposure to the air, nor by being long kept under water: it indeed loses its lustre in the air, and becomes tarnished. When however, silver has been long exposed to the air of churches, theatres, or other places of human resort, it acquires a covering of a violet colour which deprives it of its lustre and even its malleability. This is produced by a combination of the silver with the sulphurous vapours of the atmosphere of such places: the violet or black covering is therefore a sulphuret of silver. Silver is acted upon by the sulphuric and nitric acids, but not by the muriatic. With the nitric acid, (aquafortis,) silver is dissolved into a colourless liquor, which stains of an indelible black all animal and vegetable substances. Hence it is used as a permanent ink, and for giving a black colour to the hair; but in these operations great caution is necessary, and the liquor should be much weakened by water; because it is extremely caustic and corrosive. Nitric acid dissolves more than half its weight of silver, the solution depositing crystals. When these are fused by a gentle heat, they are cast in molds, and form *lunar caustic,* or *lapis infernalis,* employed in surgery to open up ulcers, and destroy fungous excrescences called proud flesh.

Silver combines readily with the greater number of the metals: with gold it forms a compound of a greenish cast; and the alloy being more fusible than gold it is employed to solder pieces of that metal together.

4. *Mercury,* called also *quicksilver,* was known in very remote times, and employed by the ancients in gilding and in separating gold from other bodies, just as it is in modern times. Mercury abounds in Europe, particularly in Spain, Germany, and Hungary. The mines of Almaden in the south of Spain were worked by the Romans, and vast quantities are sent from thence to America, to be employed in separating the silver from other substances. *Almaden* is the Arabic name for *the mine,* so applied by the Moors when masters of that part of Spain. In Britain, no mercury is extracted from the earth, although *Pennant* states that mercury in its native state is found in different mountains of Scotland. It is commonly met with in slate, lime-stone or sand-stone: when united with sulphur it is called *cinnabar,* which, when reduced to a fine powder is called *vermilion,* a word brought through the French from the Latin *vermiculus,* a small worm, in allusion to the kermes-insect, from which a red dye is obtained.

At the ordinary temperature of the atmosphere, mercury is always fluid; differing in this respect from all other metals; but it becomes

solid when exposed to intense cold. By experiments made on the shores of Hudson's bay in North America, it was found that mercury congeals or becomes solid at a temperature of 39° below the beginning of Fahrenheit's scale. Mercury has been frequently congealed in this country also, by applying to it a high degree of cold, produced by the mixture of different solid substances which by their union become liquid; such as snow and potass or fixed ammoniac, &c. When thus made solid mercury may be hammered and extended without breaking. When heated to 660° it boils and may be totally distilled or evaporated from one vessel into another; and by this property it is separated from other bodies with which it may be combined. When acted upon a long time by heat and air, mercury absorbs oxygen, and is converted into a red oxyde, formerly called precipitate *per se.* When dissolved in nitric acid, evaporated to dryness, and then exposed to a strong heat, in a porcelane vessel, it assumes when powdered a brilliant red colour, usually called *red precipitate,* possessing poisonous qualities. The muriatic acid acts on mercury only after long digestion, forming muriate of mercury. If this be saturated with oxygen *corrosive sublimate* is formed. By blending completely equal parts of mercury and oxygenated muriate, *mercurius dulcis* or *calomel* is obtained. With the greater number of metals mercury unites, forming amalgams, much used in gilding. The mixture of 10 parts of mercury, and 1 of gold is spread over the metal to be gilded; by a gentle heat the mercury is driven off, and the gold adheres to the metal. The use of mercury in the tube of the barometer is founded on the fact that, its specific gravity being to that of water, as 13,568 to 1, if by the pressure of the atmosphere, the mercury in an exhausted tube stand at 30 inches, it will answer the same purposes, and with infinitely greater conveniency, as a column of water of 34 feet in height.

5°. *Copper.* Next to gold and silver copper seems to have been the first known metal. Before the method of working iron was discovered, copper was the principal material of all domestic utensils, and instruments of war. Even during the famous Trojan war, only 1200 years before our Saviour, the arms offensive as well as defensive of the warriors celebrated by *Homer,* were made of bronze, a compound of copper and tin. The name copper is brought down to us from the island Cyprus in the bottom of the Mediterranean, where the metal was produced and first made known to the Greeks. Copper is found in many parts of Britain: but the most extraordinary mine is that of Parys mountain in the isle of Anglesey. This mine had been worked at a very remote period, but had been abandoned: at last in 1768, after a long search, a great body of copper ore was discovered. The ore is lodged in a hollow with water which, being impregnated with the copper, is drawn up and distributed into pits. In this water a quantity of iron is immersed, and the particles of copper are immediately precipitated, the iron being reduced to a yellow ochre.

Copper may be hammered out into very thin leaves. Dutch leaf, or Dutch gold as it is called, is in fact only copper leaf coloured by the fumes of zinc. It is also very ductile, and such is its tenacity, that a copper wire one-twelfth of an inch in diameter is capable of supporting 302 pounds weight. Copper is not altered by water: not even at a red-heat, unless air be admitted at the same time, when the copper is oxydated. This is plain from the fact that, when water is

kept in a copper vessel, a green crust or verdegris is formed on that part which is in contact with the water. Sulphuric acid, when strongly concentrated, dissolves copper, producing crystals of a fine blue, being a sulphate of copper, commonly called *blue vitriol.* When plates of copper are exposed to the fumes of vinegar (acetous acid) it is oxydized, forming *verdegris.* This is chiefly prepared about *Montpellier* in the south of France.

Copper may be combined with most of the metals forming alloys of great utility. The alloy of copper with gold is easily formed by fusing the metals together. This alloy is much used, because the copper hardens the gold, without injuring its colour; and the hardness is greatest when 7 parts of gold are alloyed with 1 of copper. The gold coin of Britain and France consists of 11 parts of gold and 1 of copper. The alloy of these metals is more fusible than gold alone; it is therefore employed to solder together pieces of that metal. A mixture of copper and platinum takes a fine polish, and is not liable to tarnish; on which account it has been advantageously employed in mirrors of reflecting telescopes. The alloy of silver with copper is harder and more sonorous than silver alone. The silver coin of this country consists of 15 parts of silver and 1 of copper: that of France is much purer, containing $19\frac{4}{5}$ of silver to 1 of copper. The amalgam of copper cannot be formed by simply mixing it with mercury, even when heat is applied; because the heat necessary to melt the copper makes the mercury evaporate or sublime. The easiest way of making this amalgam is to triturate the mercury with common salt and verdegris. Copper unites very readily with tin, forming compounds of great utility, such as cannon or gun-metal, bell-metal, bronze for statues, &c. and mirrors of telescopes. The addition diminshes the ductility of copper, increasing its hardness, fusibility, tenacity, and sonorousness. Bronze and gun-metal consist of from 6 to 12 parts of tin, with 100 parts of copper. The *halcos* of the ancient Greeks, and the *æs* of the Romans were compounds of copper and tin, of which sharp-edged instruments, even swords and spear-heads were formed, and of which many are preserved to the present time; while those of *sidèros, ferrum,* iron, being very liable to destruction from moisture, are extremely rare. The ancient copper coin was of the same composition, and not brass as is commonly said. Bell-metal consists in general of 3 parts of copper to 1 of tin; it is of a greyish white, very hard, elastic and sonorous. Mirrors of telescopes are made of 1 part of copper and 3 of tin; the alloy is very hard and receives a fine polish; but other compounds have been found to answer equally well. Vessels of copper, especially when used as kitchen-utensils, are usually lined with a thin coat of tin, to prevent the copper from oxydizing, or turning to rust, and thereby to prevent any part of that poisonous metal from mixing with the food in the vessels. The interior surface of the vessel is scraped very clean with an iron instrument, and rubbed over with sal ammoniac. The vessel is then heated, and a little pitch thrown into it, and allowed to spread over the surface; a bit of tin is then applied all over the hot copper, which instantly assumes a silvery whiteness. These previous steps are necessary to render the copper perfectly pure and metallic; for tin will not combine with the rust or oxyde of copper. The coat of tin thus applied is extremely thin; nor is there any method known of laying it on thicker. More tin may indeed be applied, but even a moderate heat

will melt this additional quantity and cause it to run off. A copper pan 9 inches in diameter, and $3\frac{1}{4}$ inches deep acquired by being tinned an additional weight of only 21 grains, or the 23d part of an ounce. In tinning vessels lead is frequently mixed with the tin, a practice that cannot be too severely condemned.

6. *Iron,* the most useful, and the most abundant of all the metals, was neither so early known nor so easily wrought as gold, silver or copper. Moses, who was born 1635 years before our era, mentions the ores from which iron was drawn, and the furnaces for working it; he tells us that of iron were made swords, knives, axes, and tools for cutting stone. The knowledge of iron is said to have been carried into Greece from Asia 200 years after Moses; yet during the Trojan war, still later by 200 years, iron was in such estimation, that the Grecian hero Achilles proposed a ball of that metal as a prize, in the funeral games he celebrated in honour of his friend Patroclus. It appears that at the same period none of the weapons of war were made of iron.

Iron is attracted by the magnet, and is itself the substance which constitutes the lodestone; but when it is perfectly pure it very soon loses the magnetic virtue. It is malleable in every degree of temperature; and its malleablity increases in proportion as the heat augments: it cannot however be hammered out so thin as gold or silver, or even as copper. The ductility of iron is much more perfect; for it may be drawn out into wire as fine as a human hair. Such is its tenacity that an iron wire one-twelfth of an inch in diameter will support very nearly 550 pounds avoirdupois.

When exposed to the air the surface of iron is soon tarnished, being gradually changed into a brown or yellow powder called rust. This change takes place the more rapidly when the atmosphere is moist, because the iron then the more readily combines with the oxygen of the air, for which it has a very strong affinity. When iron filings are kept in water, in a heat not under 70°, they are gradually converted into a black powder called *martial ethiops,* and a quantity of hydrogen gas is emitted. If the steam of water be made to pass through a red-hot iron tube, it is instantly decomposed. The oxygen of the steam combines with the iron, and the hydrogen gas passes through the tube to be collected in proper vessels. This is one of the easiest ways of obtaining pure hydrogen gas. By these facts we discover that iron has a strong affinity for oxygen, since it is able to detach it from air and water; iron has also a capacity of taking fire and burning with great vivacity. Twist a small iron wire into the shape of a cork-screw by rolling it round a cylinder, fix one end of it in a cork, and to the other attach a small bit of cotton thread dipped in melted tallow, set fire to the cotton, and plunge it while burning into a jar filled with oxygen gas. The wire catches fire from the cotton, and burns with great brilliancy; the iron combining with the oxygen and so being converted into an oxyde. When iron filings are kept red-hot in a vessel, and constantly agitated, they turn to a dark red powder formerly called *crocus marlis.* Common rust of iron is merely this oxyde combined with carbonic acid gas. If equal quantities of iron filings and sulphur be mixed together, and formed into a paste with water, the sulphur decomposes the water by absorbing the oxygen so rapidly, that the mixture sometimes takes fire, even though buried under ground.

This fact has been considered to afford an explanation of the origin of volcanos.

When 16 parts of iron, 16 of phosphorus, and 1 of charcoal powder are fused together in a crucible, the substance formed is magnetic, very brittle, and when broken is of a white colour. This substance possesses the qualities of cold-short iron, which is brittle when cold, but malleable when hot; the brittleness may however be removed by heating the cold-short iron strongly with limestone. Carburet of iron is found native in various parts of Britain, particularly in Cumberland; and is well known as plumbago or black-lead. When pure it contains 90 parts of carbon and 10 of iron; but is generally mixed with clay, and flinty substances.

Iron is divided into three sorts; cast or pig-iron, wrought or soft iron, and steel. *Cast* iron is the name of the metal when first separated from the ores, which consist generally of the oxyde of iron and clay. The objects of the manufacturer are to separate all the clay, and to restore the oxyde to a metallic state. These two objects are attained at once by mixing the ore, when reduced to small pieces, with a certain portion of lime-stone and charcoal, and exposing the whole to a very violent heat in furnaces constructed for the purpose. The charcoal or the coke (pit-coal charred) having lost their oxygen absorb it from the oxyde, and the iron is restored to its metallic state. The lime combines with the clay, both being melted into a kind of fluid glass. The iron itself now metallic is also fused by the violent heat, and being specifically heavier than the glass, falls down and is collected in the bottom of the furnace, while the glass floats on the surface. A hole in the lower part of the furnace is now opened, and the iron flows out into moulds prepared to receive it. The cast-iron thus obtained is scarcely malleable at any temperature, and generally so hard as to resist the file: it is extremely brittle, and can neither be hardened nor softened by cooling or heating; it is more sonorous than steel. Of iron in this state many valuable utensils, and parts of important machines, as well as iron cannon are formed.

The most considerable iron works in England are those of *Colebrook-dale* on the Severn in Shropshire; but the most extensive iron manufactory in the world is that at *Carron*, in Stirling-shire in Scotland. Here were first cast the short light and manageable cannon of all sorts, (some even 8 inches in the bore, and discharging a ball of no less than 68 pounds,) called from the foundery *Carronades*, now universally adopted by all the maritime powers of the world.

Wrought or *soft* iron is obtained in this way. The cast iron is put into a furnace, and kept melted by means of the flames of the combustibles made to play upon its surface. In this state it is constantly stirred by the workmen, that every part may be exposed to the air. In about an hour the hottest part of the mass begins to heave and swell, emitting a lambent blue flame. This operation is continued for another hour, when the iron is brought into a state fit to be wrought. As the process advances, the iron gradually acquires more consistency, and at last, notwithstanding the continuance of the heat, it completely congeals into a solid mass. The iron is then taken out of the furnace while hot, and violently beaten by means of very weighty hammers driven by machinery. This hammering not only makes the particles of the iron run the closer

together, but drives away several impurities which would otherwise continue to adhere to it. This is the iron fit for the forge.

When small pieces of iron are placed in alternate layers, with powdered charcoal in a close crucible, and kept in a strong red-heat for 8 or 10 hours, a substance is formed called *steel*, distinguished from pure iron by several properties. Steel is unmalleable while cold; at least it acquires this property by being immersed while red-hot into cold water; for this immersion adds greatly to the hardness of steel, but has no effect upon plain iron. Steel is brittle, it resists the file, cuts glass, gives sparks with flint, and retains the magnetic virtue for any length of time. By being made red-hot, and then suffered to cool very slowly, it loses its hardness. When red-hot it is malleable, and may then be hammered into plates much thinner than can be made of iron. By being repeatedly exposed to the fire in an open vessel, and then hammered, steel is again brought back to wrought iron.

The ancients to whom the change of iron into steel was known, attributed it in general to the qualities of certain rivers and waters into which the hot iron was plunged. The swords of Spain were famous of old, and preferred by the Romans to those made in any other country. *Bilbilis*, the birth-place of the epigrammatic poet *Martial*, the remains of which are still perceptible near Calatayud on the banks of the Xalon, the ancient *Salo*, which falls into the Ebro above Saragossa, was celebrated for furnishing the finest sword-blades, tempered in the cold waters of that river. A *Toledo* blade was long held in high estimation, the steel manufactured there being tempered in the Tagus. A fine and durable edge is also given to swords in the mountains of Biscay in the north of Spain, by brandishing them, when made red-hot, in the keen frosty air of the winter months.

Cast Steel, the most valuable of all sorts of steel was discovered about 1750 by *Mr. Huntsman* of Sheffield. It is more fusible than common steel, and therefore cannot be welded with iron. It is used for making razors, surgeons' instruments, and other similar purposes; and the degrees of temper are judged of by the colours, some of them very beautiful, which the steel exhibits, in different degrees of heat with access of air. At first the steel becomes of a pale yellow, then of a deeper yellow, next reddish, afterwards deep blue, and at last bright blue. At this point it becomes red-hot, and all colours disappear. With gold an alloy may be made of iron, extremely hard and applicable to cutting instruments: platinum is usually found alloyed with iron: on iron mercury does not act; it is usually therefore kept in iron vessels; by the addition of zinc, however, an amalgam of iron may be obtained.

7. *Tin.* This metal was known in the most remote ages of antiquity. The Phœnicians of Tyre and Sidon, procured it from Spain and Britain; at least the islands called *Cassiterides*, (in Greek the islands of tin) are supposed to be the Scilly isles, then much more extensive than at present, together with the adjacent parts of Cornwall, where it is still found in great abundance. The importance of tin in giving to wool the fine scarlet and purple colour, was probably known to the Phœnicians, who concealed with the utmost care from other nations the source from which they drew that metal; pretending the invaluable Tyrian purple was wholly produced from a particular shell-fish found on their own shores.

Tin is very malleable; for tin-leaf, or tin-roll as it is called, is about one thousandth part of an inch in thickness, and might if wanted be beat much thinner. The ductility and tenacity of tin are however much inferior to those of the preceding metals; for a tin wire of one-twelfth of an inch in diameter will not support a weight of more than thirty-one pounds. When tin is melted in an open vessel, its surface is soon covered with a grey powder, which is an oxyde of tin formed by the union of the metal with the oxygen of the air. By continuing the heat the powder changes its colour, and at last becomes yellow, being the *putty* employed in polishing glass and other hard bodies, and for rendering glass white and opaque, converting it into enamel. By heating tin in concentrated nitric acid, it is turned into a white powder deposited in the bottom of the vessel, containing 72 parts of tin, and 28 of oxygen. When equal parts of this white oxyde and sulphur are mixed and heated in a retort, a substance consisting of 60 parts of the oxyde, and 40 of sulphur is obtained, which is a sulphureted oxyde of tin, commonly called *aurum musivum,* used by japanners to produce a beautiful gold colour.

Tin may be combined with most of the metals; but the greater number of the alloys are brittle. Mercury very readily dissolves tin when cold; and the two metals may be combined in any proportion by pouring mercury into melted tin. The amalgam of 1 part of tin, and 3 of mercury is used for *silvering,* as it is erroneously called, the backs of glass mirrors. Although tin do not readily combine with iron, yet the affinity between the two metals is sufficiently shown by the formation of *tin-plate,* or *white-iron,* in French *fer blanc.* This most useful alloy is made in this way. The thin iron plates are well scoured, and then put into a pickle of oil of vitriol, (sulphuric acid) diluted with water, to dissolve the oxyde or rust that may have remained in spite of the scouring. Being again scoured, and washed, the iron plates are dipped into a vessel of melted tin, having its surface covered with fat or oil, to prevent its oxydisement by contact with the air. Coming thus into immediate communication with the metallic tin, it is not only covered on the surface, but completely penetrated by the melted metal. Tin and lead may be combined in any proportion by fusion; forming an alloy harder and more tenacious than tin. These qualities are at the greatest when the alloy contains 3 parts of tin, and 1 of lead. Tin and lead are the principal ingredients in pewter; this alloy being more fusible than either of the metals alone, is used by plumbers as a solder.

8. *Lead* was known in very early times, and was by the ancients considered as nearly related to tin. It differs from other metals in this, that it neither becomes harder nor specifically heavier by being hammered. It is very malleable; but its ductility is not great: and so weak is its tenacity, that a wire of $\frac{1}{12}$th of an inch in diameter will not bear a weight of $18\frac{1}{2}$ pounds. Lead is found in many parts of the British isles. The mine of *Arkingdale* in Yorkshire is at present the first in England. The mines of *Lead-hills* in the mountains of Clydesdale in Scotland are, by foreign naturalists, held to be the richest in Europe. They produce also a proportion of silver which usually accompanies lead ore. In the brooks of the same mountains are found grains of gold, in former times before the discovery of America an object of national attention.

Lead is generally found in the form of *galena* a compound of lead and sulphur in various proportions, sometimes 84 of the former substance to 16 of the latter. Lead is not directly acted upon by water; but moisture assists the action of air upon it. Hence the white crust on the sides of leaden vessels containing water, just at the surface of the water. When lead is kept melted in an open vessel, the surface is soon covered with a thin grey skin or dross. If this be removed, another pellicle will soon be formed; and by continuing the operation the whole lead will be changed into the same oxyde. This substance heated and agitated in an open vessel becomes first of a greenish grey colour, and at last yellow, in which state it is the *massicot* used in painting. Thin plates of lead exposed to the vapour of warm vinegar are gradually corroded, uniting with the oxygen, and converted into a heavy white power used in painting under the name of *white-lead.* If massicot be ground to a fine powder, put into a furnace, and constantly stirred while the flames play upon its surface, it is in about 48 hours changed to a beautiful red powder, called *minium* or red-lead. As all the oxydes of lead are easily converted by heat into glass, and in that state will combine with almost every other metal but platinum, gold and silver, this property becomes of great utility in separating gold and silver from the inferior metals with which they happen to be united. The gold or silver is melted down along with lead, and kept in that state for some time, in a flat cup called a cupel, made of burnt bones or wood-ashes. The lead is vitrified and sinks into the cupel, carrying with it all the metals which were mixed with the gold and silver, and leaving these last on the cupel in a state of purity. This process is called *cupellation.* The lead afterwards extracted from the cupel is *litharge,* a half vitrified substance of a high colour, being an oxyde of lead more or less mixed with oxydes of other metals. When lead is exposed to the action of acetic acid, (the strongest distilled vinegar) in the open air, it is oxydised, and the oxyde is dissolved as it is formed. This acetate of lead has many names, such as *sugar of lead, sugar of saturn, extract of saturn,* &c. Having been strenuously recommended by *Goulard,* a surgeon of Montpellier in the south of France, as an excellent application in cases of inflammation, it came to be called *Goulard's extract or tincture of lead.* By dyers and calico printers, this substance is much used to fix their colours.

Lead may be combined with most of the metals; with nearly an equal quantity of copper it forms the substance employed to make printers' types for very large characters.

9. *Nickel* is found in different parts of Germany, Sweden, &c. of a reddish brown colour not unlike copper, and was indeed taken for copper until 1751, when *Cronstedt,* the celebrated Swedish naturalist, ascertained it to be a new metal. When perfectly pure nickel is of a fine silvery colour, and a little softer than iron. It is attracted by the magnet as strongly as iron, and may like it be converted into a magnet, pointing to the north like the common magnetic needle. Nickel has been procured that was not magnetic, but this property it was found was owing to the presence of arsenic, which has the singular power of destroying the magnetic virtue of iron, and all other metals susceptible of that virtue.

10. *Zinc* was known to the ancient Greeks by the name of *cadmian,* from *Cadmus* who first taught them the use of it: at least they knew a

certain mineral by that name which, when united with copper, formed brass. This mineral must therefore have contained a good deal of zinc. The first time this metal is mentioned is in 1280, by Albertus Magnus, who called it the marcasite of gold. The word *zinc* is first seen in the writings of Paracelsus who died in 1541. It is now often called *spelter* by workers in metals. Zinc is never found pure; and it was not till 1721 that a method of separating it from its ore was discovered in Germany. The ores of zinc are abundant, generally accompanying those of lead, particularly galena. They are in general called *calamine*, but when united to sulphur, they are called *blende*, or vulgarly *black jack*. Zinc forms as it were the limit between the malleable and the brittle metals. It is of a brilliant white colour with a shade of blue, consisting of a number of thin plates adhering together. When raised to a very strong red-heat in an open vessel, zinc takes fire, burning with a brilliant flame, and emitting a large quantity of very light white flakes: this oxyde is called *flowers of zinc*.

Zinc combines with almost all the metals; and some of its alloys are of great importance. One part of zinc is sufficient to destroy the ductility of one hundred parts of gold. With mercury it forms an amalgam employed to rub on electrical machines, in order to excite their electricity. With copper zinc readily combines, forming one of the most useful of all the metallic combinations. The metals are usually combined together by exposing to heat alternate plates of copper and zinc in the state of calamine, which is a native oxyde of zinc combined with carbonic acid. When the zinc does not exceed the 4th part of the copper the alloy is the well known substance *brass*. This compound is more fusible than copper, and not so apt to tarnish. It is malleable, and may be drawn into wire. When the alloy contains three parts of zinc and four of copper it assumes a colour nearly that of gold, but it is not so malleable as brass. It is then called *pinchbeck*, from the name of the artist who first employed it, and *princes metal*, from Prince Rupert, nephew of Charles the First, who invented it. Zinc and tin may be easily fused, forming a compound harder than zinc, which is often the principal ingredient in making *pewter*.

II. *Brittle and easily fused.*

1. *Bismuth* is of a reddish white colour, almost without taste or smell: when smartly struck with a hammer it breaks, and is therefore not malleable, nor can it be drawn into wire. When dissolved in nitric acid, and water is poured into the solution, a white powder is thrown down consisting of 81 parts of bismuth, and 18 of oxygen. This oxyde is used as a paint under the name of *pearl white*. This substance has been used as a *cosmetic*, or to ornament and improve the complexion. It is however very injurious to the skin which it renders black, and has besides very hurtful effects on the constitution in general. Bismuth unites readily with tin, and is therefore employed, on the continent, but not in Britain, in manufacturing pewter. When 2 parts of bismuth, and 3 of lead are combined, the compound possesses a tenacity ten times greater than that of lead alone. When 8 parts of bismuth, 5 of lead, and 3 of tin are melted together, a white alloy

is obtained, which is so fusible as to liquify at a heat of 212°; it therefore remains melted under boiling water.

2. *Antimony.* The ancients were acquainted with an oxyde of this metal, called by the Greeks *stimmi,* and by the Latins *stibium.* This mineral was used by the ladies of Asia also, as we learn from the *Old Testament,* to give a black tinge to the eye-brows. No metal has so much attracted the attention of physicians as antimony; one party extolling it as an infallible remedy for every disease, and another decrying it as a most virulent poison. Antimony is of a greyish colour with a good deal of brilliancy: when rubbed it gives out to the fingers a peculiar taste and smell. If 75 parts of antimony and 25 of sulphur be fused together, a sulphuret of antimony is obtained, in which state this metal is generally found native; and when the sulphur was separated, the remainder was called *regulus of antimony.* Eight parts of the oxyde of antimony, and one of the sulphuret being fused together, a red half-transparent *glass of antimony* is produced; but if the sulphuret be increased to two parts the compound is a yellowish red, called *crocus metallorum.* If the sulphuret be increased to four parts, the compound is opaque, and of a dark red. This is *the liver of antimony* of the apothecaries. With lead the combination of one sixteenth of antimony forms *the metal of printers' types.* A small portion of the oxyde of antimony may be dissolved in the acetic acid and wine, for the emetic liquor called *antimonial wine;* with the acid of tartar the oxyde forms the salt *emetic tartar,* or *antimoniated tartrite of potass.* It consists of 35 parts of tartaric acid, 40 of oxyde of antimony, 17 of potass, and 8 of water. The famous medicine known as *James's powders* is a compound of phosphoric acid, lime, and oxyde of antimony, in the proportion of 43 parts of phosphate of lime to 57 of antimony, forming a white powder partially soluble in acids, and a very energetic emetic; in small doses it only promotes perspiration.

3. *Tellurium* is of a bluish white colour, between lead and zinc, of considerable brilliancy, and in its internal structure resembles antimony. It was found in Transylvania, and first discovered to be a new metal in 1782: its properties however are hitherto but little known.

4. *Arsenic* is often found native in various parts of Germany, in masses of various irregular shapes. It is of a leaden grey colour, and is always alloyed with some iron, often containing also silver and sometimes gold. When heat is thrown upon arsenic with the blow-pipe, it emits a white smoke, with a strong smell of garlic, burns with a blue flame, gradually evaporates, and deposits a white powder. Arsenic is perhaps the most brittle of all the metals, falling to pieces under a very moderate blow of the hammer, and very easily reduced to a very fine powder in a mortar. The point of heat at which it melts is not known, because being the most volatile of all the metals it sublimes without melting when exposed in a close vessel to a heat of 540°. When exposed to a moderate heat in contact with air, it sublimes in the form of a white powder, called *white arsenic.* This oxyde is of a brittle compact glassy appearance, having a sharp acrid taste which at last leaves an impression of sweetness, and is one of the most virulent poisons known. Arsenic combined with sulphur by heat forms a red glassy body called *realgar,* which is sometimes used as a paint; and if the sulphur be in a smaller proportion the compound is

the fine yellow powder called *orpiment* also used in painting; but as well as the realgar dangerous in the use. Copper combined with arsenic in a crucible forms a brittle white substance, which when united with a little bismuth or tin becomes *white copper*, or *white tombac*. One curious property of arsenic is that it destroys the magnetic virtue of iron, and of every other metal susceptible of that virtue.

III. *Brittle and difficultly fused.*

1. *Cobalt* is a heavy mineral of a grey colour, which has been used in Europe, for these three centuries past, to tinge glass of a blue colour. It was not however till 1733 that the nature of the metal was ascertained. Cobalt is of a grey colour with a shade of red, and by no means brilliant. When violently heated to 130° of Wedgewood, it melts; but no heat has hitherto been able to make it evaporate. Like iron and nickel it attracts the magnet, and may be converted into an artificial magnet. Oxyde of cobalt when freed from arsenic is called *zaffer*, which fused with 3 parts of quartz, and 1 of potass, forms a glass of a beautiful blue colour; this glass pulverized becomes *smalt* used in some kinds of painting. The blue used in colouring starch is also made from it; it is likewise used by painters of earthern ware, enamellers, &c.

2. *Manganese* has been long known and used in the manufacture of glass, for destroying the green or yellow tints in it; on which account it is commonly called glass-makers' soap; it also gives a violet colour to glass and porcelane. When pure manganese is of a greyish white and pretty brilliant, it requires a heat of 160° of Wedgewood to fuse it; so that next to platinum it is the most difficult to be fused of all the metals. It is almost always found in the state of a black oxyde consisting of 40 parts of oxygen, and 60 of pure manganese. As it readily unites with copper it has been proposed to substitute manganese in the place of the noxious metal arsenic, in the composition of white copper or tombac, used in various arts. With mercury it has not yet been combined; but it readily unites with iron; and indeed it has scarcely ever been found free from some mixture with iron.

3. *Tungsten* is found in Sweden, very heavy and of an opaque white colour; hence its name, which signifies heavy stone. It is one of the hardest of the metals.

4. *Molybdenum.* By this Greek term, and by the Latin *plumbago*, seem to have been signified oxydes of lead; but by the moderns they are applied without distinction to all substances having these properties; to be light, soft, easily broken, of a dark colour and a greasy feel, leaving a stain on the fingers. The distinction between these substances was first ascertained by Scheele in 1778. The one consisting of iron and carbon he called *plumbago*, already noticed as a carburet of iron, commonly called *black lead;* the other substance he found to consist of sulphur and a whitish powder possessing the properties of an acid.

5. *Uranium*, is of an iron grey colour: it is found in Germany combined with sulphur.

6. *Titanium* was found lately in Cornwall, as an oxyde united with iron.

7. *Chromium* is of a whitish yellow colour, commonly called the *red lead ore of Siberia* where it was first found.

8. *Columbium* is so called as having been found in North America, originally discovered by the illustrious navigator *Columbus*. It is of a dark brown grey colour.

9. *Tantalium* was lately discovered in Swedish Finland, and supposed to be an ore of tin.

The last five metals have hitherto been but imperfectly examined: their properties and uses are therefore still but little known to chemists.

Division Second.

The substances mentioned in the foregoing part of this chapter are of such a nature that they can be collected together in quantities, and retained, and confined in vessels fitted for the purpose, in order to be subjected to the test of experiment, and accurately examined. The substances noticed in the ensuing pages are of a very different description; for we have no way to collect and retain them to be brought under examination. They are of a nature too subtile to be confined in our vessels; and they have too strong an affinity for other bodies, to remain a moment in a separate state. The number of these unconfinable bodies at present known, or supposed to exist, is four, viz. *light*, *heat*, the matter of *electricity*, and that of *magnetism*. But as electricity and magnetism are scarcely at present considered as belonging to chemistry, and as they have both been already noticed in sections 6th and 7th of Chapter II. our attention will now be confined to the consideration of the chemical properties of the two former articles, viz. light and heat.

I. *Light.* Concerning the nature of light two different theories have been advanced by philosophers. The eminent Dutch naturalist and astronomer *Huygens*, who died in 1695, considered light to be a subtile fluid filling space, which rendered bodies visible by the undulations or waves produced in it. According to this theory, when the sun at his rising agitates this fluid, waves or undulations are excited in it, which gradually extend themselves until they strike our eyes, and then we see the sun; much in the way in which waves are produced in water, when a stone is thrown into it, or when the water strikes with force against any resisting body. This opinion was powerfully supported by the celebrated mathematician *Euler*: but the greater number of later philosophers, with *Newton* at their head, have considered light to be a real substance consisting of small particles constantly flying off from luminous bodies, moving in all directions in straight lines, and rendering bodies visible and luminous by passing from them into the eye. This theory Newton established on the basis of geometrical demonstration, by showing that all the phenomena of light may be properly deduced from it. Huygens and Euler on the other hand attempted to establish their scheme, rather by starting objections to the Newtonian, than by giving direct proofs of the truth of their own. These objections, however, suggested by men every way competent to discuss the question, prove that the nature and operation of light are not yet completely understood; and some of them have been lately very ingeniously revived and supported by *Dr. Young* in his lectures on natural philosophy, delivered before *the Royal Institution of Great Britain*, and

published in 1807. At present however it will be best to follow the Newtonian theory, in which light is conceived to be a real substance, proceeding in all directions, in straight lines, from luminous bodies. In section 5th of Chapter II. on *Optics* are given general remarks on the *mechanical* properties and uses of light: the business of the present portion of this work is to consider some of the *chemical* properties of that substance.

Light is capable of entering into bodies, and of remaining in them, and of being afterwards extricated from them, without any alteration. Many substances become luminous by merely exposing them to light, losing that luminousness when removed into a dark place, and again recovering it when brought back into the light; and so on as often as is required. Some natural substances possess this property in a high degree, as the stone of *Bologna*, so called because it was found in 1630, near that city in the north of Italy. It is a compound of sulphur with the heavy earth thence called *barytes* or *ponderous spar*. The late *Mr. Canton* discovered a composition of burnt oyster-shells and sulphur which possessed the property of absorbing and giving out light, in a remarkable degree. This is *phosphorus*, a name borrowed from the Greek language, signifying the light-bearer.

Light not only enters into bodies, but combines with them, and becomes one of their constituent parts. It has been long known, that different kinds of animal substances, just when they begin to putrify, shine in the dark: this is most noticeable in certain fishes as the whiting, the herring, and the mackerel. If four drams of either of these be put into a phial, containing two ounces of sea-water, and the phial be set in a dark place, a luminous ring appears on the surface of the liquid, within three days, and the whole liquid becomes luminous when shaken. When the liquor is frozen the light disappears; but returns when it is thawed. By a moderate heat the light is increased; but a boiling heat destroys it altogether.

Almost all bodies absorb light; but they do not all give it out again like phosphorus and animal bodies, some absorbing one coloured ray, others another, while they reflect the rest; this is the cause of the colours of bodies. A red body for instance reflects the red rays, and absorbs all the others. Hence a white body reflects all the rays and absorbs none, whereas a black body absorbs all the rays and reflects none. The absorption of light produces very sensible changes in bodies. Plants for instance will vegetate in the dark; but then their colour is always white, they have scarcely any taste, and are found to contain but a very small proportion of combustible matter. In a short time however after their exposure to light their colour turns to green, their taste is more intense, and the quantity of combustible matter is sensibly increased. Of this fact a striking instance is related below, from a note by *Professor Robison* of Edinburgh, in his edition of *Dr. Black's* lectures on chemistry.* Another remarkable example

* "Having occasion (says Professor Robison,) in autumn 1772, to go down to inspect a drain in a coal-work, and crawling along I laid my hand on a very luxuriant plant, having a copious deep-indented white foliage quite unknown to me. I enquired of the colliers what it was. None of them could tell me, It being curious, I made a sod be carried up to the day-light, to learn of the workmen what sort of plant it was: but no body had ever seen any like it. A few days after, looking at the sod, as it lay at the mouth of the pit, I observed that the plant had languished and died for want of water, as I imagined. But looking at it more attentively, I observed that a new vegetation was

of the agency of light is the change produced by it in reducing the oxydes or calces of metals to their original metallic state. The red oxydes of mercury (red precipitate), and of lead, (minium or red lead,) become much lighter in colour when exposed to the sun. From these, and similar facts it is evident that light has the property of separating oxygen from several oxydes. It is a peculiar property of light that its particles are never found to cohere together, so as to form masses of any sensible magnitude; a difference from other bodies to be accounted for only on the supposition that its component particles, instead of attracting, repel each other.

The different sources from which light is emitted are these four: 1. The sun and stars. 2. Combustion or burning. 3. Heat; and 4. percussion or striking of one body against another.

The light emitted by the stars possesses precisely the same properties as the light of the sun. The cause of light being continually emitted by those bodies, and the source from which it proceeds, will probably for ever baffle the utmost exertions of the human understanding; at any rate however such enquiries do not properly fall within the cognisance of chemistry.

In every case of combustion, light is emitted. Now combustion of simple combustibles and metals is the act of combining the combustible with oxygen. Consequently the light produced during combustion must have existed previously, combined with either the combustible or the oxygen.

If heat be applied to bodies, and continually increased, there is a certain temperature or degree of heat at which, when they arrive, they become luminous; and this whether the body be or be not in contact with air: thus a piece of iron wire becomes red-hot while immersed in melted lead. To this general law there is one remarkable exception; for it does not appear that the gases become luminous even at a much higher temperature.

The last source of light is percussion. It is well known that when flint and steel are smartly struck against one another, a spark always appears, capable of setting fire to tinder or gun-powder. The spark in this case is a small particle of the iron, which is driven off and catches fire during its passage through the air. This is therefore a case of combustion. But light often appears when two bodies are struck against each other, when both are certainly incombustible. Thus sparks are emitted when two pieces of quartz stone are smartly struck together; even under water.

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beginning, with little sproutings from the same stem, and that this new growth was of a green colour. This instantly brought to my recollection the curious observations of *Dufay*, and I caused the sod to be set in the ground and watered. I was the more incited to this, because I thought that my fingers had contracted a sensible aromatic smell, by handling the plant at this time. After about a week this root set out several stems and leaves of common *tansy*. The workmen now recollected that the sods carried down into the pit had been taken from an old cottage-garden hard by, where a great deal of tansy was still growing in the grass. Having more sods of the same plant brought up from the pit, the foliage was luxuriant and white like the first, but it gave no aromatic smell whatever. All these last plants withered away in the air, although carefully watered, and in each from the same stalk sprouted fresh stems and foliage of tansy, full of the ordinary juices and flavour of that plant, and of a full green colour. I have repeated the same experiment on lovage, mint, and carraways, which all throve very well below in the dark, but with a blanched foliage, not shooting upwards, but lying flat on the ground; and in not one of them did the foliage bear any resemblance to the genuine leaves of the plants. All of them died down when brought into day-light; and the stocks than produced the proper plants, in their usual dress and having all their distinguishing smells."

II. *Caloric.* Nothing is more familiar to us than *heat:* to define it therefore is quite unnecessary. When we say that *a person feels heat,* that *a stone is hot,* we are easily understood; yet in these expressions the words *heat* and *hot* have distinct meanings. In the first case we signify the animal sensation of heat, and in the second the cause of that sensation. When we put our hand on a hot stone, we experience the sensation of heat, and the cause of this sensation we now term *caloric,* from the Latin word *calor* signifying heat or warmth. The phenomena in which caloric is concerned are the most intricate and interesting in chemistry, and the study of them has contributed in a very particular manner to the advancement of the science. They involve however some of those parts of chemistry which are still exceedingly obscure, and which consequently have occasioned the most important disputes among chemists. For these reasons the nature and properties of caloric, or the matter of heat, claim very particular attention. In the present work however it will be impossible to do much more than merely to point out the names of those properties.

1. *Nature of caloric.* On the nature of caloric philosophers have maintained two different opinions; some supposing caloric to be like gravity, merely a property of matter, consisting somehow or other in a peculiar motion of its particles; others on the contrary conceiving caloric to be a real distinct substance. The latter opinion seems best to correspond with experiment; the former however has been lately supported by very plausible arguments. At any rate we have the same reason to consider caloric to be a real substance as we have to believe light to be a real substance. For particular statements of the arguments, and facts adduced on each side of this difficult question, the reader is referred to the *System of Chemistry of Dr. Thomas Thomson* of Edinburgh, and the *Lectures on Natural Philosophy and the Mechanic Arts, of Dr. Thomas Young* of London; both excellent and very late publications.

From observing the light and heat produced by rays from the sun or a fire at a proper distance, we are apt to believe them to be inseparable. This however is not the case: for it has long been ascertained by philosophers, that the light of the moon, even when concentrated by a lens so strongly as to surpass, in point of illumination, the brightest candles or lamps, does not produce the least sensible heat; and yet these candles or lamps produce a very sensible heat. Here then we have rays of light, consisting of the seven prismatic coloured rays, which produce no heat. Hence as we have here rays of light which excite no heat, we must conclude, that the rays from the sun and bodies in combustion, which do excite heat, must consist of a mixture of rays of light, and rays of caloric. These two sorts of rays are very easily separated in this way. If a glass mirror be held before a fire it reflects the rays of light, but not the rays of heat: a metallic mirror on the contrary reflects both. The glass mirror becomes hot; but the metallic mirror does not change its temperature. If a plate of clear glass be suddenly interposed between the face and a glowing fire, it completely intercepts the warming power of the fire, without causing any sensible diminution of its light: consequently the glass stops the caloric, but allows the light to pass through. If however, the glass be kept in this position till its temperature be raised to the highest, the rays of heat are no longer intercepted, but

pass through the glass as freely as those of light. From these and similar experiments it appears that the light of the sun is composed of three sorts of rays, the colorific which produce colour, the calorific which produce heat, and the deoxydizing which, separating oxygen from the oxydes or calces of metals, restore them to their original metallic state.

The rays of caloric are reflected by polished surfaces in the same way with those of light: they are also refracted in the same way in passing through transparent substances; and both probably proceed from the sun with the same velocity of nearly 200,000 miles in a second. In this supposition the particles of heat must be equally minute with those of light; consequently neither the addition of caloric nor its abstraction can sensibly affect the weight of bodies. The particles of caloric agree in another property with those of light; they are never found cohering together, and forming masses of perceptible bulk: and whenever they are forcibly accumulated in any space or spot they are ready to fly off in all directions, separating from each other with inconceivable rapidity; a property necessarily supposing in the particles of heat or caloric a strong mutual repulsion. Thus it appears that caloric and light resemble one another in various properties. Both are emitted from the sun with the same velocity; both are reflected by polished surfaces, and refracted by transparent bodies; both consist of particles mutually repulsive, and producing no sensible effect on the weight of bodies exposed to them. In this particular however they differ, that light produces in us the sensation of sight; while caloric produces the sensation of heat.

2. *Motion of caloric.* This motion is of two kinds; through some bodies caloric moves with the same rapidity as through free space, or at least its velocity is not sensibly diminished by its passage: in this way it moves through air, and several other transparent substances. But through other bodies caloric moves extremely slowly. Thus if we put the point of a bar of iron, 20 inches long, into a common fire, and attach to the other end a thermometer; 4 minutes will elapse before the thermometer begin to ascend. Caloric or heat must therefore take 4 minutes to pass through 20 inches of an iron bar. The difference between this motion and that of 200,000 miles in one second through the air, is prodigious.

When caloric passes through a body with undiminished velocity, it is said to be *transmitted* through it; but when its velocity is much retarded in its passage, we say it is *conducted;* and this retardation must be occasioned by some affinity or attraction between caloric and the conductor. All solid bodies are conductors of caloric; particularly earthy and stony bodies, the metals and vegetable and animal substances. This is however to be understood with certain limitations; for all solids are not conductors in all situations in respect to the quantity of heat. Thus sulphur, at the temperature of 60° is a conductor of heat; but when heated to 212° (boiling water,) it melts or is volatilized, and ceases to be a conductor. In the same way ice conducts caloric when at the temperature of 20° or at any other degree below 32° the point of freezing: but at 32° ice changes its state, melts into water, and then is no longer a conductor.

At first sight liquids and gaseous bodies would appear to be all also conductors: but as the parts of fluids are easily moved among them-

selves caloric has on them an effect very different from that produced on solids. One change produced by caloric on bodies is expansion or increase of their bulk, attended by a proportional diminution of their specific gravity. Whenever therefore caloric combines with a stratum of particles, the whole stratum becomes specifically lighter than the other particles. In solids this produces no change of situation among the particles; but in fluids, if the heated stratum of particles be below the other cool strata, become specifically lighter it rises above them, being thus buoyed up to the surface of the fluid. The colder strata thus falling down come in contact with the caloric, and then in their turn rise to the surface; until the whole fluid is heated. But if the heat be applied above to the surface of the fluid the caloric is conducted downwards through it in the same way as in a solid.

If we place the ends of a bar of iron, and a piece of stone of equal dimensions, in the fire, the outer end of the iron will be sensibly hot long before the outer end of the stone. Caloric is not therefore conducted through all bodies with equal rapidity. The best conductors of heat are the metals. According to experiments it would appear that the power of different metals to conduct heat may be ranked in this order: viz. first *silver*, then *gold*, *copper* and *tin* about equal, *platinum*, *iron*, *steel* and *lead*, much inferior to the others. Next to the metals the stones are the best conductors: bricks are much worse than stones. Glass is a bad conductor of heat; and hence it is so apt to crack when suddenly heated or cooled. Next to these bodies come dried woods: charcoal is a bad conductor. Feathers, silk, wool, and hair are still worse conductors than any of the foregoing bodies, and hence arises their fitness for articles of clothing. The heat communicated to those substances, either internally from the body of the animal, or externally from the sun or a fire, passes very slowly through them, and is with difficulty communicated to the cold air around. By very ingenious and accurate experiments on the above substances it has been found, that their power of conducting heat is inversely as the fineness, or directly as the coarseness of their texture. That is to say that the finer the hair or fibres of the wool, down, &c. the more obstinately do they retain heat, and the warmer must be the clothing made of them.

3. *Distribution of caloric or temperature.* As caloric is capable of moving through all bodies, it has a tendency to distribute itself among all contiguous bodies, until they all acquire the same temperature. A bar of iron may be made red-hot by keeping it in the fire: but if it be taken from the fire, and exposed to the open air, giving out the heat it had received, it becomes gradually colder and colder, till it arrive at the temperature of the bodies around it. On the other hand if we cool down the iron bar, by keeping it for some time in snow, and then carry it into a warm room; it does not continue at the low temperature acquired from the snow, but becomes gradually hotter, until it arrive at the temperature of the air of the room. If however the quantity of cold bodies brought into a warm room bear a considerable proportion to the contents of the room, the quantity of caloric distributed through the bodies at first in it, being now extended to others having by their coldness a great capacity for caloric, the temperature of the whole will be proportionally lowered. A similar but opposite effect will follow the introduction of a large hot body into a cold room.

If a number of liquors heated to different degrees of temperature, and in equal quantities, be mixed together, the temperature of the whole will be a mean of the different temperatures of the several equal quantities of liquids. Thus if equal quantities of six different liquids be mixed together, at the respective temperatures of 18°, 32°, 40°, 50°, 60°, and 70°, the sum of these temperatures 270° divided by 6 will give 45° for the mean temperature of the mixture.

But heat or caloric is not only *conducted* from one body into another by contact; it is also *radiated*, or it is dispersed in all directions from a heated body, as light spreads out in rays from the sun. This *radiation* however is only a modification of conducting; for a hot body suspended in the air in the middle of a room will gradually cool. If it be suspended in the exhausted receiver of an air pump, it cools more slowly, and the more completely the air is exhausted the more slowly does the cooling go on. Hence it appears, that the heat is abstracted from the heated body rapidly in proportion to the density of the air, with which it is in contact.

4. *Effects of caloric.* These are reducible to three changes in bodies in respect to bulk, to state, and to combination.

1. Changes in the bulk of bodies. It is a maxim that every addition or abstraction of caloric makes a corresponding change in the bulk of the body exposed to this alteration in the quantity of its heat. In general heat enlarges a body, and cold diminishes it: but to this there are some exceptions. The enlargement of bodies by heat is termed *expansion*, and its opposite is *contraction*. Expansion is not only one of the most general effects of heat; but it furnishes us with the means of measuring all the other effects. Bodies are differently expanded by heat according to their state. Solids expand but little; liquids much more, and air or other gaseous bodies the most of all. For instance 100 cubic inches of common air by being heated from the freezing to the boiling point of water, that is from 32° to 212° expand to a space containing 137.5 cubic inches; but the same augmentation of temperature will expand 100 cubic inches of water only to 104.5 inches; and 100 inches of iron by the same change of temperature is enlarged only about one thousandth part of their original bulk, or to 100.1 cubic inches. Hence it appears that water by the given increase of temperature expands 45 times more than iron; and that air expands 375 times more than iron, and a little more than 8 times more than water.

It is to the expansibility of fluids that we owe the advantage of measuring heat by the instrument called, from that property, the *thermometer*, (See Chap. II. section 3. *Pneumatics.*) A glass tube closed at one end, and blown into a hollow globe or bulb at the other, is partly filled with mercury. When the bulb is plunged into a hot body, the mercury by the accession of the heat expands or *rises* in the tube; and when it is plunged into a cold body, the heat leaves the mercury which then contracts or *falls*. In making experiments with the thermometer, however, we are always to remember, that the rise or fall of the mercury does not indicate merely the change of temperature in the body to which it is applied. For the mercury itself expanding proportionally more as the heat increases, a degree at a high temperature will be larger than one at a low temperature. Thus supposing the medium temperature between freezing and boiling water, that is between 32° and 212° to be, as it is in calculation, 122°; if the scale of the thermometer

be extended upwards, the boiling point will not be at 212° but at 218° 4. On the other hand if we fix the freezing and boiling points in the common way, marking them 32° and 212° on the thermometer, then the medium temperature between these two points will not be, as in calculation, 122°, but 118°. 8.

To this general effect of heat, some exceptions occur, in which expansion is produced not by an increase but by a decrease of temperature. Some liquid bodies are at their maximum of density, or occupy the least space, at a particular temperature; and when heated above that point, or cooled below it, they expand or increase in bulk. Another class of liquids, when cooled down to a certain point, suddenly become solid, and in this change they expand or increase in bulk. A remarkable instance of the first class of liquids we have in water. Its greatest density, or the point at which it occupies the least space, is at $42\frac{1}{2}$ degrees of Fahrenheit's thermometer. If it be cooled below that point it is found to expand gradually until at 32° (the freezing point) the expansion amounts to $\frac{1}{160}$ of the whole expansion of water then heated from $42\frac{1}{2}$° up to the boiling point 212°: and this expansion is equal at any given point above or below $42\frac{1}{2}$°, that is to say the expansion of water is the same at 32° as at 53°. The bodies which undergo an expansion when changing from a liquid to a solid state by the decrease of heat are very numerous. Not only water when converted into ice undergoes this expansion, but all bodies which by cooling assume the form of crystals. The prodigious force with which water expands in the act of freezing is well known. Glass bottles filled with water are commonly broken in pieces when the water freezes. The academicians of Florence burst a brass globe, the cavity of which was only an inch in diameter, by filling it with water and freezing it. The force exerted by the expansion of that small quantity of water was estimated to be equal to that of a weight of 277 pounds. This expansion of water at the instant of its assuming a solid form is supposed to be owing to a tendency observed in water to arrange its particles in one determinate manner, so as to form prismatic crystals crossing each other at angles of 60 and 120 degrees. Prodigious indeed must be the force with which they arrange themselves in this way, since it enables so small a quantity of water to overcome so great a mechanical pressure. When liquid substances are converted into solids, they either form prismatic crystals, or a mass in which no regularity of arrangement can be perceived. In the first case expansion accompanies solidification; but in the second case it is accompanied by contraction. Water and all the salts are instances of the first, and tallow and oils of the second. In these last bodies solidification takes place, not instantaneously as in water and salts, but slowly and gradually, becoming at first tough and viscous, and at last quite solid. The same thing happens to honey and some of the metals, as mercury, which also contracts in its solidification.

2. Changes in the state of bodies produced by heat. All substances as far as hitherto known exist either in the state of solids, or of liquids, or of elastic fluids or vapours. In a great number of cases the same substance may be successively observed in all of these states. Thus sulphur is usually found in a solid state; but when heated to 212°, (the heat of boiling water,) it becomes liquid; and at a temperature still higher, about 570°, it is converted into an elastic vapour of a deep brown colour. Thus also water in our climate is usually a liquid;

but when cooled down to 32° it becomes solid or ice, and when heated to 212° it boils and is converted into steam or vapour.

All solids, a very small number excepted, may be converted into liquids, by heating them sufficiently; and on the other hand every liquid, spirit of wine excepted, may be converted into a solid, by exposing it to a sufficient degree of cold, that is by abstracting the heat from it. All liquids may, by heating them be converted into elastic fluids; and many solids undergo the same change; lastly, the number of elastic fluids which by cold are condensible into liquids or solids is by no means inconsiderable.

When solids are changed by heat into liquids the change in some cases takes place at once, and instantaneously, in others it takes place very gradually. The change of water into ice is an example of the first; the melting of glass, wax, tallow, &c. is an example of the second. In general those bodies which crystallize, or put on regular prismatic figures, have no interval between solidity and fluidity; but those bodies that do not crystallize have the property of appearing progressively in all the intermediate states. Solid bodies never begin to assume a liquid form till they are heated to a certain temperature, and this point of temperature is constant in every particular body. This temperature has different names, according to the usual state of each body. When this is usually observed in a liquid state, the temperature at which it turns to a solid is called its freezing or congealing point; but when the body is usually solid, the temperature at which it grows liquid is called its melting or fusing point.

It was formerly the opinion that solids were converted into liquids by a small addition of heat, after they are once raised to the melting point, and that they returned again to the solid state, on a very small diminution of the quantity of heat necessary to keep them at that temperature. This opinion was universally received by chemical philosophers, until 1762 when the late celebrated *Professor Black* of Edinburgh, then of Glasgow, introduced to the world a very different theory, the result of multiplied and most sagacious experiments. His theory was this, that when a solid is converted into a liquid, a much greater quantity of heat enters into it than is immediately perceptible by the thermometer. This great quantity of heat does not make the body apparently warmer: but it is necessary for rendering it liquid. On the other hand, when a liquid body becomes solid, a very great quantity of heat leaves it, without sensibly lowering its temperature; and the state of solidity cannot be induced without the abstraction of this great quantity of heat. Or, in other words, when a solid is converted into a liquid, it combines with a certain dose of caloric, without any augmentation of its temperature: and when the liquid is again turned to a solid, the dose of caloric leaves it, without any diminution of its temperature. Thus a combination a of a certain dose of caloric with ice causes it to become water, and the abstraction of a certain dose of caloric from water changes it to ice. The caloric or principle of heat thus combined in water, or which produces fluidity being imperceptible to the thermometer, Dr. Black called it *latent, or concealed heat:* but later philosophers have introduced the expression *caloric of fluidity.*

It hence appears, that by the combination of heat with solids they become liquid; but a still more remarkable change is produced by the application of heat to liquids; for almost all of them when raised to a

certain temperature assume the form of an elastic fluid, invisible like air, and possessing the same mechanical properties. Thus water by boiling is converted into steam, an invisible fluid eighteen hundred times more bulky than the water which produced it, and as elastic as air. These fluids retain their elastic form as long as their temperature remains sufficiently high; but when cooled down again they lose that form, and are converted into liquids. Some liquids are gradually changed into elastic fluids at every degree of temperature; of this sort are water, alcohol, ether, and volatile oils; on the other hand, some others, as sulphuric acid and the fixed oils, never begin to assume the form of vapour until raised to a certain temperature. When all other circumstances are the same, the evaporation of liquids increases with their temperature. When the heat is applied, as is common, to the bottom of the vessel containing the liquid, after the whole liquid has acquired a certain temperature, the particles at the bottom being nearest the heat are first changed into an elastic fluid, which being vastly lighter than the liquid itself rise through it to the surface like air-bubbles, throwing the whole into violent agitation, and then pass off into the atmosphere. The liquid is then said to *boil.* Every particular liquid has its proper fixed boiling point; water for instance always boiling at the temperature of 212°: and it is remarkable that, after a liquid has begun to boil, it never becomes any hotter, however strong the fire, and however long it may be acted on by the fire. But the boiling point of any liquid depends on the pressure of the atmosphere on its surface; if this be increased a greater heat will be necessary, and if it be diminished a less heat will be necessary. From many experiments it is found that in a perfect vacuum or vessel deprived of air all liquids boil at about 145 degrees of Fahrenheit lower than in the open air; therefore water would boil in a vacuum at 67°, and alcohol at 34. On the other hand in a Papin's digester, a strong vessel so closely shut that no air can escape from it, water will bear to be heated as high as 300°, or even as 400°, without boiling.

3. Changes in the combination or composition of bodies. Caloric not only increases the bulk of bodies and changes their state from solids to liquids and elastic fluids, but it decomposes a great number of bodies altogether, either into their elements, or by causing those elements to combine together in a different manner. This decomposition is, in many cases, owing to the different volatility of the ingredients. Thus when weak spirits or alcohol and water are heated, the alcohol being very volatile flies off, before the water arrive at its point of evaporation. All bodies containing combustibles are decomposed by heat: the metallic alloys however have hitherto in general resisted all efforts to decompose them by heat. When two combustible ingredients, and likewise oxygen occur together in bodies, they are always very easily decomposed by heat. This is the case with the greater number of animal and vegetable substances.

5. *Quantity of Caloric.* On this head three questions arise, namely, to determine, 1. The relative quantities of caloric in bodies, or the quantities necessary to produce a given change of temperature. This is usually termed *specific caloric.* 2. The absolute quantity of caloric existing in bodies. 3. The phenomena of *cold* or of the absence of caloric.

1. If equal weights of water and mercury, at different temperatures,

be mixed together and agitated, it is natural to expect that the mixture will acquire the mean temperature. Suppose the heat of the water to be 100°, and that of the mercury 50°; it is reasonable to conclude that the water will be cooled 25°, and the mercury heated 25°, so that the mixture will be at the temperature of 75°, being the half of the two temperatures, 100° and 50°. But upon trial the result is extremely different; for the temperature is found to be 88°: so that the water has only given out 12°, and the mercury has gained 38°. On the other hand if equal weights be mixed together of water at 50° and mercury at 100°, the temperature after agitation will be only 62°, so that the mercury has given out 38°, and the water has gained 12°. This experiment shows that the same quantity of caloric is not necessary to raise mercury a given number of degrees as to raise water the same number. The caloric that raises mercury 38° raises water only 12°; consequently the caloric which raises the temperature of water 1°, will raise the same weight of mercury $3\frac{1}{6}$°. If other substances be tried in the same manner they will all be found to differ from each other in the quantity of caloric which is necessary to heat each to a given sensible temperature, or its specific caloric.

2. The absolute quantity of caloric in bodies has employed the ingenuity of various very eminent philosophers, particularly *Dr. Irvine* of Glasgow, and *Mr. Dalton* of Manchester. No theory has however yet been adopted which will explain every phenomenon, in which the absolute or real quantity of heat in any body is concerned.

3. Of cold or the absence of heat. It was before observed, that hot and cold, in common language, are relative terms. When I lay my cold hand on a warm iron, the caloric enters my hand until it become as warm as the iron: I then have the sensation of heat or warmth: but if I grasp a piece of ice in my warm hand, caloric passes from the hand into the ice, and I have the sensation of cold. Hence we see that what we call cold is only a relative term to signify the absence of heat. In the beginning of the last century it was supposed by many eminent naturalists that cold was produced, not by the abstraction of heat, but by the addition of some positive real contrary substance. According to them cold was a substance of the nature of salt, greatly resembling nitre, constantly floating in the air, and wafted about by the wind in very minute corpuscles, to which they gave the name of *frigorific particles*, or such as produced cold. According to those philosophers, the frigorific particles converted water into ice by insinuating themselves like wedges between the particles of the water, and thereby destroyed their mobility. But since Dr. Black's discovery of the true cause of the freezing of water, from the abstraction of the caloric of fluidity, those frigorific particles have been entirely banished from the regions of philosophy.

A very great degree of cold may be produced by mixing together different solid bodies which suddenly become liquid. The first experiments on freezing mixtures were made by Fahrenheit; but the subject was much more completely investigated by Mr. Walker, in a paper in the Phil. Trans. for 1795; since which time other improvements have been introduced, particularly by the use of muriate of lime, (fixed ammoniac,) which when mixed with snow produces a very intense cold. Equal quantities of snow or pounded ice and common salt, mixed together, will lower the temperature from 32° (the cold of ice,) to 0° or

the beginning of the scale. Three parts of muriate of lime mixed with two parts of snow lower the temperature from 32° to 50° below the beginning of the scale; and 2 parts of muriate of lime with 1 part of snow, will lower the temperature from 0° to 66° below 0°.

In order to produce these curious effects the salts employed must be fresh crystallized, and newly reduced to a very fine powder. The vessels in which the mixture is made should be very thin and just large enough to hold it, the materials being mixed together as quickly as possible.

Cold is also produced by evaporation; and by it ice is artificially made even in the scorching climates of India, where none is naturally produced. The ice-makers on the banks of the Ganges dig pits in large open plains, the bottom of which they strew with sugar canes, or the dry stems of maiz or Indian corn. Upon this bed they place a number of shallow unglazed pans made of an earth so porous that water oozes through them. These pans are filled towards evening, in the winter season, with water that has been boiled, and are left in that situation till the morning, when more or less ice is found in them according to the temperature of the air; there being more formed in dry and warm weather, because the evaporation is then the greatest, than in cloudy weather, although it may feel colder to the human body. In this operation every thing is calculated to produce cold by evaporation. The beds of canes, &c. on which the pans are placed, suffer the air to have a free passage to their bottoms; and the pans constantly oozing out water to their external surface, are cooled by the evaporation of it. In Spain are used a kind of jars called *bujaros*, made of an earth so porous, and only half-baked, that the outside is kept moist by the water which filters through the jars; and though placed in the sun the water becomes cold almost to freezing. It is a common practice in China to cool wine or other liquors by wrapping a wet cloth round the bottle, and hanging it up in the sun. The water in the cloth evaporates, and cold ensues. Ice may be produced at any time by evaporating ether; equal parts of alcohol, and sulphuric acid distilled together. If a glass vessel containing water, and surrounded with a cloth, be dipt two or three times into ether, allowing the ether each time to evaporate from the cloth, the water in the glass will soon be frozen. The following very beautiful experiment, by which water was made to freeze by the cold produced by its own evaporation, was lately invented by *Professor Leslie* of Edinburgh. The arrangement for this operation consists in placing water in a cup of porous earth, suspended within the receiver of an air-pump, and placing a little below the cup in a broad shallow vessel, sulphuric acid which very powerfully attracts water; so that an extensive surface of the acid shall be presented. On extracting the air by the pump, and consequently rarefying what remains in the receiver, the evaporation of the water is accelerated, and of course the degree of cold produced by the evaporation is increased. This however would soon be checked by the presence of the watery vapour in the receiver, were it not absorbed by the sulphuric acid, almost as fast as it is formed; by which means the rarefied air is kept constantly dry, and the evaporation is allowed to proceed with the same rapidity. The temperature therefore continues to fall until the water shoot into crystals of ice: and even after the water is entirely congealed, the ice continues to undergo evaporation until it wholly disappear. By

pushing the rarefaction of the air to a sufficient extent Professor Leslie was able to freeze quicksilver, and to preserve it frozen for several hours together; the bulb of a thermometer containing it being first coated with ice, and then suspended within the receiver, at the distance of half an inch from the surface of the sulphuric acid, and the exhaustion carried to the utmost.

These powers of producing evaporation and cold might be improved to very useful purposes. If the air-pump were made more perfect, and if a substance were employed that would attract and absorb moisture more powerfully than sulphuric acid, and the operations performed on a large scale, very important effects might be produced. Water might thus easily be converted into ice in the hottest climates, and exsiccation carried to a high pitch, as in the drying of gun-powder, without the possibility of the dreadful consequences of the explosion of mills now so frequent, and in drying for preservation objects of natural history, from the animal or vegetable kingdoms, more speedily than can be done at present, and without applying heat, by which the colour and the structure of such objects are so liable to be injured.

It was before mentioned that water and other liquids, when heated to a certain point, are converted into vapour, in which state they fly off, carrying with them a certain portion of heat. By this process the remaining liquid is gradually cooled down to the freezing point of the liquid employed.

6. *Sources of Caloric.* These may be reduced to five. Heat radiates constantly from the sun; it is evolved during combustion; it is in many cases extricated from bodies by percussion, friction, and mixture.

1. *The Sun.* The temperature produced by the direct action of the sun's rays seldom exceeds 120° : but a much higher temperature would be produced by direct rays, could we prevent the heat from being carried off by the surrounding bodies. This has been proved by the following experiment. A small box was lined with fine dry cork, charred on the surface to make it black and spongy, in order that it might absorb the greatest possible quantity of the sun's rays, and be as bad a conductor of heat as possible. The box was covered with three very thin vessels of flint-glass, a substance which transmits more caloric than any other kind of glass, arched above, and one-third of an inch asunder. The box was placed on down contained in a pasteboard cylinder. A thermometer placed in this apparatus rose often, in a clear summer day, to 230°, and once to 237°. Even when set before a bright fire, the thermometer rose to 212°, the heat of boiling water.

2. *Combustion.* There is perhaps no fact more wonderful in itself, more interesting on account of its utility, or which has more closely occupied the attention of chemists than *combustion.* When a stone or a brick is heated it undergoes no sensible change excepting in its temperature; and when left to itself it soon cools again and becomes as at first. With combustible bodies on the contrary the case is very different. When heated to a certain degree in the open air they suddenly of themselves become much hotter, continue for a time intensely hot, and send out a copious stream of caloric and light to the surrounding bodies. This emission after some time diminishes and at last ceases altogether. The combustible has now undergone a complete change, being converted into a substance no longer combustible, and possessing properties very different from those of the original body. Thus when charcoal is

kept for some time at the temperature of about 800°, it kindles, becomes intensely hot, emitting light and heat. When this emission ceases the charcoal has all disappeared except an inconsiderable residuum of ashes; being almost entirely converted into carbonic acid gas which makes its escape, unless the experiment be conducted in proper vessels. If this gas be collected it is found to exceed greatly in weight the whole of the charcoal consumed. According to the received theory of combustion or burning, it consists of two things, first a decomposition, and next a combination. The oxygen of the atmosphere in the state of gas is combined with caloric and light. During combustion this gas is decomposed, its caloric and light escape, while its base combines with the combustible and forms the product. This product is no longer combustible, because its base being already saturated with oxygen it cannot combine with more. The French chemists perceiving that in all cases of combustion, the oxygen of the atmosphere combines with the burning body, too hastily concluded oxydizement and combustion to be the same thing. But this was a great mistake; for oxygen often combines with substances, as azote, muriatic acid, and mercury, without producing either light or heat: whereas the extrication of light and heat, as well as oxydizement, must be effected, in order to produce combustion.

3. *Percussion.* When a piece of iron is smartly struck with a hammer, it becomes red-hot; and the production of sparks of fire by striking flint against steel is too familiar to require notice. No heat however has ever been perceived to accompany the percussion of liquids nor of soft bodies which easily yield to the stroke. This evolution of heat from bodies by percussion seems to be owing to the condensation permanent or temporary of the body struck. For the specific gravity of iron before hammering is 7.788; but after hammering 7.84. The particles therefore are forced nearer together, and some of the caloric must necessarily be pressed out to the surface, where it becomes sensible in different ways. Even air when condensed into one half its original bulk acquires an additional temperature of 50°; and if air be rarefied so as to fill double its original space its temperature is lowered 50°. By sudden condensation or percussion as much caloric is evolved as to raise the heat of some of the particles of bodies high enough to enable them to combine with the atmospheric oxygen. That this happens in the collision of flint and steel is certain; for the sparks produced are found to consist merely of small pieces of the iron, heated red-hot by uniting with oxygen, in passing through the air. Iron and flint give no sparks in the vacuum of an air-pump; because no oxygen exists there; but sparks are produced under common spring water.

4. *Friction.* Fires are often kindled by smartly rubbing pieces of dry wood against one another. It is well known that heavy loaded carriages will take fire by the friction between the axle-tree and the nave of the wheel, unless some lubricating substance as grease, oil, &c. be introduced between the parts in contact. The native Americans procure fire by friction with great dexterity. They take two pieces of dry wood, one nine inches long and the other quite flat. Cutting on the first piece a blunt point, and pressing it upon the other, they whirl it round as swiftly as possible, holding between both hands as we do the trundle of a chocolate-mill; and in a few minutes the wood takes fire. The heat excited by the boring of a brass cannon, which is made

to revolve rapidly, and press strongly on the point of the borer, is sufficient to make water boil. Caloric which appears in consequence of friction is not produced by an increase of the density of the bodies, nor by an alteration in their specific caloric, nor by the decomposition of the oxygen of the atmosphere. Whence then is the heat of friction derived? To this question chemists and philosophers are not yet able to give a satisfactory answer. It is not however improbable that electricity may in some way be concerned in producing this phenomenon. Electricity is perhaps different from caloric; but it seems to contain it; and electricity can be accumulated by friction: the heat produced by friction may therefore result from certain qualities of electricity.

5. *Mixture.* It is well known that, in a great number of instances, when two substances enter into a chemical union, a change of temperature takes place. In some the mixture grows colder than before; in others it becomes much hotter. Of the mixtures that produce cold notice has already been taken: at present some observations will be given on those mixtures which produce heat.

In almost all mixtures producing a change of temperature water is an essential part; even in some gases water is a principal ingredient. When salts which contain a great portion of water, such as carbonate of soda, (soda or barilla,) sulphate of soda, (Glauber's salts) muriate of lime, (fixed ammoniac) are dissolved in water, the temperature is considerably *lowered,* the fall being proportioned to the rapidity of the solution. But when the same salts, previously deprived of their water by exposure to heat, are dissolved, the temperature of the mixture is considerably *raised.* It may be laid down as a rule to which no exception is known that when the compound formed by the union of two bodies is more fluid or more dense than the mean fluidity or density of the two bodies before mixture, then the temperature sinks, and the mixture becomes colder than before. On the other hand when the fluidity or the density of the compound is less than that of the two bodies, the temperature rises, and the mixture becomes hotter than the ingredients; and the rise is very nearly in proportion to the difference. Thus when snow and common salt are mixed together, they gradually melt and become liquid. During the process of melting the temperature continues at or lower than zero: but whenever the solution is completed the temperature rises. On the other hand when spirits and water are mixed together, a condensation takes place; for the specific gravity of the mixture is greater than the mean of the ingredients; accordingly the mixture becomes hot: this heat is sensible to the mouth in drinking spirits and water. When 4 parts of sulphuric acid, (oil of vitriol,) and 1 part of water are mixed together, the density of the compound is increased greatly beyond the mean of the two liquids; accordingly the temperature of the mixture suddenly rises to about 300°.

From these facts we learn why cold is produced during the solution of salts which contain an abundance of water. This water, while a part of the salts, is in a solid state: but when dissolved it becomes liquid. Since these salts, if they be deprived of their water, produce heat during their solution, it cannot be doubted that the water, before it dissolve them, first combines with them so as to form a solid, or at least a solution of considerably greater density. Whenever water becomes solid, a considerable proportion of heat is evolved. Hence the reason that a great deal of heat is produced by sprinkling water upon

quick-lime. A portion of the water combines with the lime, forming a dry powder totally destitute of fluidity. For the same reason heat is produced when quick-lime is thrown into sulphuric acid. In the same way we may account for the heat thrown out during fermentation and putrefaction.

Fluidity is in all cases produced by the combination of caloric with the body that becomes fluid; hence a mixture that becomes fluid must absorb caloric, or it must produce cold. On the other hand when a fluid body becomes solid it gives out heat which then becomes sensible.

SECOND.—*Of Compound Bodies.*

Compound bodies are such as consist of two or more simple substances combined together. Were all simple bodies susceptible of combination, the compound bodies would amount to a prodigious number: but this is not the case. Neither hydrogen, for instance, nor azote have ever been combined with metals: we are besides too little acquainted with the nature of caloric and light to be able to treat separately of the compounds into which they enter.

Compound bodies are of two kinds. Some are formed by the combination of two or more simple substances; thus phosphoric acid consists of phosphorus and oxygen, and oil consists of carbon and hydrogen. Other compound bodies are formed by combining simples with compounds, or compounds with compounds; thus phosphate of ammonia consists of phosphoric acid and ammonia, and volatile liniment consists of oil and ammonia. The combinations of simple bodies are termed *primary compounds,* and those of compound bodies are *secondary compounds.*

I.—Of Primary Compounds.

These may be arranged in five classes, namely, *Alkalies, Earths, Oxydes, Acids, Compound-combustibles.*

1. *Alkalies.* The term alkali is of Arabic origin, introduced into chemistry in relation to the properties of the plant kali. When this plant is burnt, the ashes washed in water, and the water evaporated to dryness, a white substance remains which was called *al-kali,* signifying the kali. This substance may however be obtained from other substances besides the kali or glass-wort a marine plant; hence the term alkali is applied to all bodies possessing the following properties, viz. that have a caustic or burning effect on the tongue,—that are volatilized by heat,—capable of combining with acids,—soluble in water even when combined with carbonic acid,—and capable of converting into green the blue colour of vegetables.

The alkalies at present known are these three, *Potasse, Soda,* and *Ammonia.* The first and second are called *fixed* alkalies, because it requires a strong red heat to make them evaporate; and the third is called the *volatile* alkali, because it readily assumes the form of gas or vapour, and is dissipated by a very moderate degree of heat.

1. *Potasse.* If a quantity of wood be burnt to ashes, and the ashes be afterwards washed repeatedly with water, till it come off free from

all taste, and if this liquid be filtrated and evaporated to dryness, the substance remaining behind is *potash*, so called because it is generally obtained from the ashes of wood burnt in kitchen or other fires. This however is not in a state of purity: but when heated to redness many of the impurities are dissipated; the substance becomes much whiter than before, and is then called from its colour *pearl-ash*, still nevertheless combined with carbonic acid gas, which blunts all its properties. But it may be obtained perfectly pure by mixing it with twice its weight of quick-lime, and ten times its weight of pure water. The mixture is boiled for some hours in a clean iron vessel, or allowed to remain for two days in a close glass vessel, shaking it occasionally. Being then filtered, and again boiled with a quantity of alcohol equal to one-third of the pearl-ash employed, the liquid separates into two parts; the impurities in the bottom, and the pure potash dissolved in alcohol in the top; by evaporation the spirit flies off, and the potash remains behind, a fine white solid body, in perfect purity, which, to distinguish it from the common pot-ashes of commerce, is called by a modern Latin name *potassia*, and in chemical English *potasse*.

The progress of this preparation of potasse is very evident; the lime attracts and unites with the carbonic acid, for which it has a strong affinity, and the spirit or the evaporation carries off every thing else, leaving the potasse in perfect purity.

Potasse was long distinguished by the name of the *vegetable alkali*, being chiefly obtained from vegetables. It was also called *salt of tartar*, because it may be obtained by burning the salt called tartar. Late chemists give it different names, as *tartarine, vegalkali, kali, lixiva*. Potasse in purity is a white brittle substance, having a smell resembling that produced by the slaking of lime: its taste is remarkably acrid; and the substance is so exceedingly corrosive that, when applied to the human or any other animal body, it destroys it almost instantaneously. On this account it is called *caustic*, and is used by surgeons as a *cautery*, (both from the Greek word signifying to burn) to open abscesses, and destroy hurtful excrescences. When exposed to the air potasse attracts moisture, and liquifies, combining at the same time with the carbonic acid, for which it has a great affinity. It has also a very strong attraction for water, one part of which, in the ordinary state of the atmosphere, dissolves two of potasse, forming a transparent but very dense solution like oil; in which state it is commonly used by chemists. Two parts of potasse, and one of sulphur melted in a crucible form *sulphuret of potasse*, a brownish substance resembling the liver of animals, and thence called liver of sulphur. Potasse combines with none of the metals. By means of a powerful galvanic battery the ingenious *Sir Humphrey Davy*, has lately decomposed potasse, finding it to be composed of oxygen, and a peculiar metallic base which he thence calls *potassium*.

2. *Soda*, or the fossil or mineral alkali, being once thought to be peculiar to the mineral kingdom, was known to the ancients under the names of *nitron*, and *nitrum*. It is found in large quantities, combined with carbonic acid, in various countries, particularly in Egypt where it was called *natron*, the same with the *natar* of the Hebrew Scriptures. Our common sea salt is a compound of soda and muriatic acid. But the soda of commerce is obtained from the ashes of different species of the *salsola* or glass-wort, plants that grow on the sea

shore. The soda of commerce is also called *barilla*, because those plants are so called in Spain. The greater number of sea-plants growing upon our own rocky shores called by us *kelp*, and in France *varec*, also yield soda when burnt.

The soda of commerce is never free from carbonic acid, common salt, and other matters: but it is purified by the same process as potasse. Soda is of a greyish white colour, and agrees with potasse in taste, smell, and action upon animal substances: but it is specifically lighter. When exposed to the air it attracts moisture and carbonic acid, but does not liquify like potasse: in a few days it dries again and crumbles down into powder. *Sir H. Davy* found it consist of carbonic acid, and a peculiar metallic base which he called *sodium*.

Soda and potasse are of great importance in human life. To them we are indebted for two articles of indispensable necessity, namely soap and glass. A compound of oil, whether animal or vegetable, with soda forms *hard* soap, and with potasse *soft* soap. Soda or potasse with flint or siliceous earth, forms glass.

3. *Ammonia.* This alkali may be obtained in this way. Put into a retort a mixture of three parts of quick-lime, and one-part of sal ammoniac in powder: plunge the beak of the retort below the mouth of a glass jar filled with mercury, and standing inverted in a bason of mercury. Apply the heat of a lamp to the retort, when a gas will come over, displace the mercury, and fill the jar: this gas is ammonia, so called because the salt from which it was procured was found abundantly near the renowned temple of *Jupiter Ammon*, or *Hammon*, in the deserts of Libya on the west of Egypt.

Ammonia is known by various names, such as the *volatile alkali*, because of its great volatility; *hartshorn*, as being often obtained by distilling deers'-horns; *spirit of urine*, as it may be drawn from that substance. In the state of gas it is colourless and transparent: the taste is acrid and caustic; but it does not corrode animal bodies: its smell is remarkably pungent and powerful as a stimulant to prevent fainting: it may be perceived abundantly in stables and cow-houses. No animal can breathe it without certain death. When made to pass through a red-hot tube of glass or porcelane, it is totally decomposed, and converted into hydrogen and azotic gas. It combines readily with water. When a bit of ice is brought into a vessel filled with this gas it melts and absorbs the ammonia; but its temperature is not altered. Water absorbs more than one-third of its weight of ammoniac gas: and in this state it is used by chemists under the simple name of ammonia. With muriatic acid it combines rapidly, forming common sal ammoniac. Ammonia combines also readily with the oxydes of gold and silver, forming compounds formerly called fulminating or thundering gold and silver, because when heated or rubbed they explode with great violence and a loud report.

2. Earths. In common language the term earth has two meanings: sometimes it signifies the *globe* or planet on which we live, and sometimes the *mould* or soil on which vegetables grow. This mould having been chemically examined it is found to contain a variety of substances mixed together without order or regularity. The greatest portion of it, however, as well as of the stones which apparently form so great a part of our globe, consists of but a small number of bodies, possessing a variety of common properties; and these bodies chemists class together

under the denomination of *earths:* Every body possessing the following properties is an earth. 1. They are insoluble in water, or nearly so, or at least becoming insoluble when combined with carbonic acid. 2. Little or no smell, at least when combined with that acid. 3. Fixed, incombustible, incapable while pure of being altered by fire. 4. A specific gravity not exceeding 4.9, much lighter than any of the metals. 5. When pure capable of forming a white powder. 6. Not altered when heated with combustibles.

The earths at present known are the following: 1. Barytes, 2. Strontian, 3. Lime, 4. Magnesia, 5. Alumina, 6. Yttria, 7. Glucina, 8. Zirconia, 9. Silica. To every one of these earths the above characters may not be all strictly applicable: but all of them possess a number of them sufficient to ascertain them to be earths.

1. *Barytes.* This mineral so called from its great weight, from the Greek *barys,* heavy, was discovered by Scheele in 1774. It is generally of a flesh colour of a foliated texture and brittle: it is common in Britain, especially in copper mines, and called *ponderous spar.* In a mineral state it is united with sulphur. It has a harsh taste more caustic than lime, and when taken into the stomach proves a most violent poison.

2. *Strontian.* About the year 1787, a mineral was carried to Edinburgh by a dealer in fossils, from the lead-mine at *Strontian,* (thus written, but pronounced *Stronteean,*) in Argyleshire in Scotland. It is sometimes transparent and colourless, but has generally a tinge of yellow or green. It is now known to exist in many parts of the world. When purified from carbonic acid or fixed air, by exposure to strong heat along with charcoal, strontian forms a porous mass of a greyish white: its taste is acrid and alkaline; and it converts vegetable blues to green: it is not poisonous: it does not melt when heated, but before the blow-pipe it is penetrated with light, and surrounded with a flame so white and brilliant, that the eye can scarcely behold it.

3. *Lime* has been known from the earliest ages. The ancients employed it in medicine: it was the principal ingredient in their mortar for building, and they used it to manure their fields. Lime is found in all parts of the world, in various states: in lime-stone, marble and chalk it is found in its greatest purity; although none of these substances can be properly called lime; but they may all be converted into it by heat, or what is called *the burning of lime.* The product of this operation, commonly called quick-lime, is what the chemist properly calls *lime.*

Lime may be procured perfectly pure by burning those chrystallized limestones called *calcareous spars,* when perfectly white and transparent, and also by burning some pure white marbles. Pure lime is of a white colour, moderately hard, but easily reduced to powder. It has a hot burning taste, and in some measure corrodes animal substances. It tinges blue colours green, and at last turns them yellow. It cannot be fused by the most violent heat of a furnace, nor even by the most powerful burning glass.

Slaking of lime. If water be poured on newly burnt lime-stone, it swells, cracks, and falls to pieces, being soon reduced to a very fine powder. In the mean time so much heat is produced, that part of the water is carried off in vapour. If the quantity of lime slaked (as it is called,) be considerable, the heat produced is sufficient to set fire to combustibles. By this effect ships and barges employed in carrying

burnt lime have, by accidentally admitting the sea or fresh water, been set on fire, and destroyed or sunk. When great quantities of lime are slaked in the dark, light as well as heat may be observed.

Lime is heavier after slaking than before. The additional weight is owing to the combination of a part of the water with the lime; and the water may be again separated by the application of a red-heat, and the lime becomes just what it was before slaking. Hence arises the heat thrown out during the slaking. Part of the water combines with the lime and becomes solid; of course it parts with its caloric of fluidity or latent heat, besides the caloric which exists in water, even in the state of ice: for when two parts of lime, and one part of ice, (each at 32° the freezing point of water,) are mixed together, they rapidly combine, and the temperature of the mixture rises to 212° the boiling point of water.

Limestone and chalk, although convertible into lime by burning, yet possess very little of the active properties of lime. Here arises the question, to what are owing the new properties of the lime? It had been long known that limestone loses a good deal of weight by being burned or calcined. Something must therefore be separated from it in that operation. Some chemists supposed this something to be water: but *Dr. Black* first ascertained in 1756, that the quantity of water separated from lime-stone in burning was not equal to the weight lost. Applying therefore a pneumatic apparatus to receive what proceeded from the calcination, he collected a quantity of air which when added to the water thrown off, was just equal to the weight lost by the lime-stone. This air existing in a fixed state in the stone he therefore denominated *fixed air*. Dr. Black's discoveries being repeated by Dr. Priestley and other chemists, this air was found to possess peculiar properties, and to be in fact what is now called carbonic acid gas, which consists of 28 parts of charcoal and 72 of oxygen. Hence we find lime proper to be a simple substance, and lime-stone to be composed of lime and carbonic acid, which is driven off in burning, leaving the pure lime behind. When this lime is exposed to the air, it attracts moisture from it and falls to powder; after which it is again soon saturated with carbonic acid, and is again converted into carbonate of lime, or to its original state of unburnt lime-stone.

Water at the common temperature of the air dissolves about one 500th part of its weight of lime: this solution is called *lime-water*, occasionally used in medicine. When this solution is exposed to the air, a stony crust is formed on its surface: when this is broken it falls to the bottom and another crust succeeds to it on the surface. In this manner the whole of the lime in the water is thrown down, by absorbing the carbonic acid from the air, and so restored to its original state of carbonate of lime or lime-stone.

Sulphur and phosphorus are the only simple combustibles with which lime combines. With the muriatic acid lime forms the muriate of lime or fixed ammonia; with the sulphuric acid it forms the sulphate of lime otherwise called *gypsum*, and commonly *plaster of Paris*, because it is dug out abundantly from the hill called *Mont Martre*, rising close on the north side of *Paris*, which it completely commands. A spot to be ever memorable in the history of our country: for of the heights of *Mont Martre*, possession was taken, on the 6th of July 1815, by the British army under the illustrious *Wellington*, in consequence of the surrender

by capitulation of the great capital of the French Empire, to the united, though comparatively small forces of Britain and Prussia. This sulphate of lime or gypsum, absorbs water very rapidly, and renders it solid, at the same time that a slight increase of heat takes place; so that if formed into a paste it dries and grows solid very suddenly, becoming thereby extremely useful for making casts of statues, bas-reliefs, cornices, and other ornamental figures, which are not to be exposed to the weather. With the fluoric acid lime forms the beautiful substance called *Derbyshire Spar,* or fluate of lime, employed in forming various ornamental figures for side-tables, chimney-pieces, &c.

Mortar. One of the most important uses of lime is the formation of mortar as a cement for building. Mortar is composed of burnt or quick-lime and sand, reduced to a paste with water. When dry it becomes as hard as stone, and equally durable; adhering very strongly to the surfaces of the stones or bricks employed in the work; the whole wall becomes in fact one strong solid stony mass. This desirable effect is however very imperfectly obtained, unless the mortar be very skilfully and carefully prepared.

The lime ought to be pure, completely free from carbonic acid, and in the state of a very fine powder; the sand should be free from clay, partly very fine, and partly course like gravel. If sea sand must necessarily be used, it ought to be well washed in fresh water, to carry off any particles of salt adhering to it, which will retain and attract moisture, and prevent the consolidation of the mortar. The water employed in the mortar should be quite pure, and if previously saturated with lime so much the better. The best proportions, according to accurate experiments, for making mortar are, *three parts of fine sand, four parts of course sand, one part of quick-lime fresh slacked, and as little water as possible.* The stony consistence which mortar acquires is owing partly to the absorption of carbonic acid from the air, by which pure lime is converted again into lime-stone; but principally to the combination of part of the water with the lime. This last circumstance is the reason that, if to common mortar be added one-fourth part of lime reduced to powder, without being slaked, the mortar when dry acquires much greater solidity than it would otherwise do. The proportion of ingredients which answers best in this case is of fine sand and cement of well baked bricks, each three parts; and of slaked lime and unslaked lime each two parts. It is also of great service to use as little water as possible in slaking the lime. It has also been discovered that an addition of burnt bones improves mortar by giving it tenacity, and rendering it less apt to crack in drying: the bones however should never exceed one-fourth of the lime employed. When a little manganese is added to mortar it acquires the important property of hardening under water. An excellent water-mortar may be made by mixing 4 parts of blue clay, 6 parts of black oxide of manganese, and 90 parts of lime-stone, all in powder; calcine this mixture to expel the carbonic acid, mix it with 60 parts of sand, and form it into mortar with a sufficient quantity of water. The best mortar however for resisting water is made by mixing with lime a quantity of *puzzuolano,* a volcanic sand so called because it is found in abundance at *Puzzuoli,* the ancient *Puteoli* at the entrance of the bay of Naples in Italy. Basalt a greyish black stone very common in our mountains, of many of which it forms the base, and often as-

suming a regular prismatic shape, as in the Giants' Causey in the north of Ireland, and in the island of Staffa and others on the west of Scotland, may be substituted for puzzuolano. The stone is heated in a furnace, thrown while red-hot into water, where it breaks into small pieces, and then passed through a sieve to reduce it to a proper fineness.

In many ancient buildings, still existing in Britain as well as on the continent, constructed by the Romans eighteen centuries ago, we see the effect of the great care employed by that extraordinary people in constructing walls. Their practice was to form the facings of the wall with small but regular cut stones, supported on each side by wooden frames, then to fill up the space between the facings with small rubble stones, amongst which was poured while *hot* a fine liquid cement of lime, fine gravel, and water beaten up to a perfect degree of incorporation. By this operation the whole wall was wrought into one solid mass of rock, harder and much more durable than any of the ingredients taken separately. We may conceive how this careful beating together of the materials produced a cement so powerful, since the discovery of *puddling* as it is called, by which earth or clay, fine gravel and water beaten up together, will form the bottom and lining of a canal or a pond, wholly impervious to water. It was therefore much more to the care and labour employed in incorporating the materials, than to the nature of the materials themselves, that the excellent qualities of the ancient cement or mortar must be attributed. Very different indeed seem to be the notions of our modern builders, especially about London, who looking on the formation of their mortar as a matter beneath their concern, intrust its manufacture to the lowest and the most ignorant of the common labourers in their employ.

4. *Magnesia.* About a century ago a priest at Rome produced for sale a white powder, as a remedy for all diseases; this he called *magnesia alba,* or white magnesia, keeping the preparation of it a profound secret. The nature and origin of the substance was however at last discovered by chemical researches. Magnesia has never yet been found in a native state; but it may be procured in this way. Sulphate of magnesia, a salt composed of this earth and sulphuric acid, exists in the water of the sea, and in many springs, particularly in some at *Epsom* in Surrey, fourteen miles south-west from London, from which circumstance it was formerly called *Epsom salt.* This salt is dissolved in water, and half its weight of potasse is added. The magnesia is immediately precipitated, because sulphuric acid has a stronger affinity with potasse than with magnesia. It is then washed in water and dried.

Magnesia is used only in medicine, being administered internally to remove acidity in the stomach. It is certainly foreign to the purpose of these pages to enter into the medicinal properties of the substances passed in review; the very general use of magnesia, and its acknowledged utility in medical practice will however justify our taking some notice of its properties and value in this respect. The following observations are extracted from a periodical work of the highest reputation *the Edinburgh Review.* In the quarterly number for February 1815 is an examination of *Mr. Brande's* dissertation on the effects of magnesia, on relieving the exquisitely excruciating torment produced by calculi or concretions in the bladder. The reviewers observe that medical men are much divided as to the harmlessness of magnesia,

when there is no acid in the stomach on which it may operate. Some hold that where there is a disposition to gout, or to calculous complaints, as well as where there is merely a tendency in the stomach to form acids; a portion of the magnesia may be taken regularly every day, especially at night;---that if it meet with any acid it neutralizes it, and carries it off by a slightly purgative effect;---and that if it meet with no acid to work upon, it lies inactive, and passes off through the alimentary canal. But the question here is, Does the magnesia in this case really so pass off harmless? It is possible that injury may be done by the lingering of the earth in the stomach and intestines, when no purgative effect is produced. It is possible that the magnesia may form the beginning of a calculous accretion or stone, or augment those already begun. Besides there is much good sense in the rule of *taking medicine of every kind, however harmless, only when it is wanted.* It can very rarely happen that the stomach should be actively forming acid, without some symptom in the shape of heart-burn, &c; and it may be early enough to take magnesia or other fit alkaline earth, when the acid begins to be felt. The magnesia should be free, not only from gross impurities, but from carbonic acid or fixed air, in order to avoid the production of flatulency, and to facilitate its union with the acid in the stomach. In every point of view therefore *calcined* magnesia, (and consequently by calcination entirely deprived of carbonic acid,) has a prodigious advantage over the common preparation; for it will neutralize the acid in the stomach much more readily and in greater quantity; of course therefore a smaller dose of the calcined than of the common magnesia will suffice; an advantage of inestimable value in the use of every medicine. Of the various sorts of calcined magnesia, that prepared by *Mr. Henry* of Manchester is deservedly celebrated for its singular purity and efficacy.

5. *Alumina.* Alum is a salt which was well known to the ancients, and employed by them in dyeing; but of its component parts they were ignorant. Later chemists have discovered alum to consist of sulphuric acid, and an earth of a peculiar nature; an earth which is an essential ingredient in *clays,* and to which they owe their peculiar properties. For this reason this earth was called *argil,* from the Latin name for clay. It is now however called *alumina,* because it is obtained in the greatest purity from alum.

Alumina is obtained in this way: dissolve alum in water, and add to the solution ammonia as long as any precipitate is formed. Decant off the fluid part, and wash the sediment in a large quantity of water, and then allow it to dry. This substance is alumina, but still retaining a portion of sulphuric acid, which may be separated by means of the muriatic acid.

When heat is applied to alumina it loses weight, from the evaporation of a quantity of water with which it is always combined, and at the same time its bulk is considerably diminished. This diminution of bulk is proportionate to the degree of heat to which it is exposed. This contraction in low temperatures seems owing to the loss of moisture; but in high temperatures, after the separation of the moisture, its contraction must be produced by the more intimate union of the particles among themselves; for it loses no perceptible weight in any temperature, however high, after being exposed to a heat of 130° of Wedgewood's scale, or the melting point of pig iron. Of this property of clay ad-

vantage was taken by the late ingenious *Mr. Wedgewood,* celebrated for his great improvements in stone-ware, to construct an instrument for measuring high degrees of heat. Two pieces of brass are united so as to form an angle, each leg being divided into equal parts. Pieces of baked clay are prepared so as exactly to fill the opening between any two given points on the legs. But if a piece be exposed to heat it will decrease in size in proportion to the intensity of the heat, and consequently fill up spaces still smaller between the legs, and the degree at which it stops will indicate the degree of heat. This pyrometer (fire-measurer,) is extremely useful for measuring relative degrees of heat for particular purposes; but sufficient experience has not yet been obtained, to establish its utility in the general measure of the temperature of bodies.

The affinity of alumina for water is considerable, and it retains it more obstinately than any other earth: hence the reason why water does not penetrate through clay. In a freezing cold it contracts more, and parts with more water than the other earths; circumstances of importance in the practice of agriculture.

Alumina has no affinity for the metals; but it combines strongly with their oxydes, particularly when the oxygen is in a great quantity, Thus the combination of alumina with the red oxyde of iron often occurs in the form of a yellow powder adhering to stones and other bodies, and known by the name of *ochre.*

Our common clay is a mixture of alumina, and silica or flint in various proportions. The alumina is in the state of an impalpable powder; but the silica is almost always in grains large enough to be discerned by the eye.

None of the earths is of more importance to mankind than alumina. It is the base of china or porcelane and stone-ware of all sorts, and of the pots and crucibles employed in manufactures which require a strong heat. It is also the principal ingredient in bricks and tyles, and is employed to the greatest advantage by the dyer and the callico-printer, by the fuller and cleaner of cloth. Fuller's earth is a combination of two parts of silica with one of alumina and small quantities of lime, iron, and magnesia.

6. *Yttria,* 7. *Glucina,* 8. *Zirconia.* Of these earths, of which the first and second have been discovered in the north of Europe, and the third in Ceylon in India, the properties and uses are hitherto too little known, to entitle them to much attention in this place.

9. *Silica.* In all parts of the world is very commonly found a very hard white stone called *quartz.* Somtimes it is found crystallized and transparent, in which state it is called *rock-crystal.* It is also frequently found in the form of sand. Quartz and several other stones resembling it, such as flint, agate, chalcedony, &c. have the property of melting into a glass when heated along with fixed alkali (potasse or soda); they have therefore been classed together by mineralogists as *vitrifiable stones.*

Silica may be obtained pure by the following process. Mix together in a crucible one part of pounded flint or quartz, and three parts of potasse, applying a heat sufficient completely to melt the mixture. Dissolve the mass formed in water, pour on it muriatic acid to saturation, and then evaporate to dryness. The remaining mass washed in a large quantity of water and dried is pure silica, a fine white powder without taste or smell.

Crystallized silica or rock-crystal, is found in many parts of the world. These beautiful natural productions are met with, of a very large size, in the crevices of the rocky precipices of the Alps and other mountains; and the occupation of a crystal-hunter is one of the most dangerous that can well be conceived. Rock-crystals when pure are transparent and colourless like the finest glass. They assume different forms; generally hexagonal prisms, terminated at both ends by hexagonal pyramids. Their hardness is very great. Rock-crystals may be imitated in different ways by dissolving silica in fluoric acid and crystallizing the solution. Some of these artificial crystals are so hard as to strike fire with steel.

Silica is one of the most important of the earths; it is the chief ingredient in those stones which constitute the basis of this terrestrial globe. It is found in greatest proportion in common flint, which generally consists of 97 or 98 parts of silica, with 2 or 3 parts of lime, alumina and water. Flints are found in great abundance in various parts of England, particularly where chalk appears. The surface of the ground in the north of Hampshire is covered with flints; and in the face of the cliffs on both sides of the British Channel at Dover and near Calais they are seen lying in regular beds, separated by thick strata of pure chalk. The manufacture of gun flints, of the highest importance in modern warfare, is chiefly confined to England and France. The operation is exceedingly simple, and an expert workman will prepare a thousand flints in a day. The art consists in striking the stone repeatedly with a mallet, bringing off at each stroke a splinter, sharp at one end, and thick at the other. These splinters are afterwards shapen at pleasure, by laying the line at which it is wished they should break on a sharp instrument, and giving it small blows with the mallet. During the whole operation the workman holds the stone in his hand, or merely supports it on his knee.

3. Oxydes. Of all the simple substances the most remarkable is *oxygen,* the cause or the principle of acidity, as the term signifies in the Greek. It combines with bodies usually in various proportions, forming compounds of various sorts according to these proportions. These compounds are of two classes, those possessing the properties of acids, and those destitute of such properties. Those of the first class are called *acids,* and those of the second *oxydes.* By oxyde then is meant a substance compounded of oxygen and some other body, but which is destitute of the peculiar properties of acids. In all cases the smaller proportion of oxygen forms the oxyde, and the greater proportion forms the acid.

Water. It was formerly mentioned that one of the simple combustible substances is *hydrogen,* that is the cause, principle, or basis of water; and that when it is combined with oxygen, water is produced. Hydrogen differs from all other combustible bodies in being combinable with only one dose of oxygen, and forming with it a compound entirely destitute of acid properties, which therefore must be ranked among the oxydes. This compound is *water,* a substance found in greater or less abundance in all quarters of the globe, without which neither animal nor vegetable life can be sustained. When pure, (in which state it can be obtained by distillation alone,) water is transparent, destitute of colour taste or smell.

As water from the ease with which it may be procured in a state of

purity, has been chosen for the standard by which the comparative weight of all other bodies may be estimated, it is of the greatest importance to ascertain its own real weight with precision. The density of water is the greatest, (that is a given weight if it occupies the least space) at the temperature of $42\frac{1}{2}°$ of Fahrenheit: other experiments place the maximum of density 2 or 3 degrees lower; but the fact is, the apparent density depends not only on the expansion or contraction of the water itself, but on those of the substances in which the water is contained during the experiments. According to a series of most accurate observations and measurements made at Paris, when the new system of weights and measures was under consideration, a cubic foot French, at the temperature of 40° of distilled water, weighed 70 pounds and 223 grains French, equal to 529452.95 grains of our troy weight. An English cubic foot of distilled water, at the same temperature, should weigh 437102.495 grains troy, or 999.0914 ounces avoirdupois. A cubic English foot of water, at the temperature of 55°, weighed, according to the experiments of *Professor Robison* of Edinburgh, 998.74 avoirdupois ounces, or only 1.26 ounces less than 1000 ounces; so that rain water which is always less pure than distilled water may, at 55°, be conceived to weigh pretty exactly 1000 ounces avoirdupois. Hence the specific gravity of water is always supposed to be 1. or the integer by which other gravities are computed. [See a table of specific gravities of several solids and fluids in Section 2. of Chap. II. on *Hydrostatics.*] But agreeably to later experiments made by *Sir George Shuckburgh,* with the nicest instruments, the weight of a cubic inch English of distilled water, at the temperature of 62°, which is the regulated standard for our measures, weighs 252.52 grains, and the cubic foot 997.4 ounces. Hence 4 cubic inches will weigh 1010 grains, and 12 wine gallons are exactly 100 pounds avoirdupois.

When water is cooled down to 32° it becomes solid, or is converted into ice. If the process go on very slowly, the ice assumes the form of crystalline needles, which cross each other at angles of 60° and 120°: these crystals have often been observed of a considerable size. While below 32°, ice may be pounded to a very fine powder: it is elastic, and is specifically lighter than water. This, as was before observed, is owing to the expansion of the water, by the tendency of its particles to arrange themselves in one determinate manner, in the act of freezing or crystallization. The specific gravity of ice is about 92 hundredth parts of that of distilled water.

When water is heated to 212° in the open air, it boils and is gradually converted into steam, a fluid invisible like air, and occupying 1800 times the space of an equal weight of water. The steam issuing from the spout of a boiling tea-kettle is invisible for a small distance: but soon coming into contact with the external air, which even close to the fire is cooler than 212°, the steam is partly condensed into vapour, and then becomes visible. The elasticity or expanding power of steam is prodigious: this is evident from the operation of the steam-engine.

Water was considered by the ancients to be one of the four simple unchangeable elements of which all bodies are composed. By distilling water in glass vessels over a slow fire a small quantity of earth was obtained; whence it was concluded that it either contained, or was converted into earth. This opinion prevailed down to 1773, when *Lavoisier* discovered that the glass vessels employed in the distillation lost in

weight exactly the weight of the earth produced. Hence it was evident that the earth which was flint proceeded from the decomposition of the glass, by the water when long acting on it, at a high temperature.

When six parts of oxygen gas and one part of hydrogen gas are set on fire or exploded in a vessel, they almost wholly disappear, and in their place is found a quantity of water, perfectly pure and free from acidity, and as nearly equal to them in weight as can be expected in experiments of so delicate a nature. The discovery of this very curious fact, that water is only a compound of two sorts of gas, was reserved for our two very ingenious countrymen *Mr. Cavendish* and *Mr. Watt* the great improver of the steam-engine, who both in 1781 were led by their experiments to the same important fact, each being entirely ignorant of the other's process and discovery.

Sea-water. The ocean is the great reservoir into which lakes and rivers empty themselves, and from which is again drawn up by evaporation that moisture which, falling in showers of rain, fertilizes the earth and supplies the waste of the springs and rivers. From this reciprocal operation the waters of the sea and those of the land might be supposed to be of the same nature; they differ however materially in taste, weight, and other properties. The sea water contains a much greater proportion of saline matters than river water, particularly of common salt. Indeed if the sea were not impregnated with saline bodies, the putrefaction of the immense mass of animal and vegetable matters which it contains would, in a short time, prove fatal to the whole inhabitants of the earth.

The absolute quantity of sea water cannot be ascertained, as its mean depth is unknown. La Place has shown that a depth of ten miles at least would be necessary to reconcile the height, to which the tides are known to rise in the main ocean to the Newtonian theory of the tides.

Sea water has a very disagreeable taste when taken up near the shore, or from the surface: but when taken up from a great depth, and away from the land, it tastes of salt only. This disagreeable taste therefore is owing to the animal and vegetable substances with which it is mixed on the surface. The specific gravity of sea-water varies from 1.0269 to 1.0285. It does not freeze till cooled down to $28\frac{1}{2}°$. Sea water holds in solution muriate of soda, (common salt,) muriate of magnesia, sulphate of magnesia, (Epsom salt,) and sulphate of lime, (gypsum): besides animal and vegetable substances. The average quantity of all the saline substances in the sea is about $\frac{1}{28}$th part. The real quantity however is very different in different parts. Water from a depth of 60 fathoms near the Canary islands contained $\frac{1}{24}$ part, at the back of Yarmouth sands $\frac{1}{32}$ part, and in the Firth of Forth in Scotland $\frac{1}{36}$ part of its weight of salt. The Baltic contains much less salt than the ocean: the Euxine and the Caspian seas contain also much less salt: but the Dead sea, or the lake now covering the sites of Sodom, Gomorrah, &c. is exceedingly salt. The water of this lake is very heavy, its specific gravity being 1.25 nearly, and it contains 44 parts of saline matter in every 100 parts of water, in this proportion, 55.6 of water, 38.15 of muriate of lime and magnesia, and 6.25 of common salt. The water of the Dead sea ought therefore to be considered rather as a mineral than as sea water.

Mineral-waters. All waters upon the land, which are distinguished from common water by a peculiar smell, taste, colour, or other properties, and which therefore cannot be employed in domestic uses, are com-

monly called mineral waters. These occur more or less frequently in most countries in the form of springs, wells, and fountains; sometimes of the temperature of the soil they pass through, sometimes warm, and in some cases even at the heat of boiling water. The effects of mineral waters in the cure of diseases, applied internally and externally, were known in the earliest times; but it was only towards the end of the 17th century that attempts were properly made to decompose them, and to discover their ingredients. *The Hon. Robert Boyle,* who died in 1691, may be considered as the first person who pointed out the method of analysing or examining water. The substances hitherto found in mineral waters are air and its component parts, acids, alkalies and earths, and salts: but in none are all these found together. Waters are divided into four classes, receiving their denomination from the peculiar substance predominating in their composition, namely the *acidulous,* the *chalybeate,* the *hepatic,* and the *saline.*

1. *Acidulous waters* contain a considerable proportion of carbonic acid (fixed air); and are easily distinguished by their acid taste, and by their sparkling when poured into a glass, like Champaign wine or brisk bottled beer. They contain in general some common salt, with a proportion of the earthy carbonates. Water absorbs carbonic acid by remaining in contact with it, and agitating them together from time to time. If a quantity of chalk, (a compound of lime and carbonic acid) be diluted with water, and sulphuric acid be poured upon it, effervescence takes place, carbonic acid gas is evolved and received in a proper vessel, there to be combined with water. In this manner the *alkaline aerated water* prepared as a medicine is obtained.

It has lately become a fashion in this country to drink *soda-water,* on account of its briskness or carbonic acid or fixed air contained in it. In cases however where no acid exists in the stomach, requiring the alkali of the soda to neutralize it, more harm than good has been done by this practice. Where no acid exists in the stomach, and a person desires only a brisk spirited and slightly stimulant beverage, simply aerated water will be found much more salutary. It is however a very important, and may become a very useful fact, that, in some parts of the country, especially where manufacturing labour has given rise to habits of indigestion and heartburn, the use of soda water among the labouring classes has actually produced the salutary effect of diminishing, to a great degree, the baneful use of spiritous liquors.

2. *Chalybeate waters* contain a portion of iron, from which they derive their name; for chalybeate in Greek signifies what consists of iron or steel. They are therefore easily known by their striking a black colour with the tincture of nutgalls, which with copperas (the green sulphate of iron) forms writing ink. The iron is generally held in solution by carbonic acid; and when this is in excess the waters are not only chalybeate but acidulous. Of this sort are the famous waters of Spa and Pyrmont in the Netherlands.

3. *Hepatic* or *sulphureous waters* contain sulphurated hydrogen gas, and may be easily distinguished by their highly fetid odour, precisely similar to that of rotten eggs, or the washings of gun barrels, both of which substances contain sulphurous gas; they also blacken silver and lead. In some cases the sulphureted hydrogen is combined with lime or an alkali. Of this kind are the waters of Harrowgate in Yorkshire.

4. *Saline waters* contain only salts, without iron or carbonic acid in

excess; and are divided into four classes, viz. those containing salts of which the basis is lime, having a taste but slightly disagreeable. They are commonly called *hard* waters, but very improperly, because they do not dissolve soap. When hard or saline water is mixed with common soap, (a compound of an alkali and an oil) the alkali of the soap unites with the acid of the salt in the water, while the earth of the salt unites with the oil of the soap, forming a compound that is insoluble in pure water: hence hard or saline waters are unfit for washing. The second class of saline waters are those in which common salt predominates, and are easily known by their salt taste: like sea water they usually contain magnesian and calcareous salts. The waters of the third class contain sulphat of magnesia, having a bitter taste and a purgative quality, such as the waters of the Epsom springs. The fourth class of saline waters contain carbonate of soda, and are easily known by their turning to green the blue colour of vegetables.

Bergman, *Kirwan*, and various other chemists of the first rank have written on mineral waters; but the most accurate and complete account of the properties and constituents of the most celebrated mineral springs, both British and foreign, will be found in *Dr. Saunders's* "Treatise on the chemical history and medical powers of the most "celebrated mineral waters," from which the following notices of a few well-known springs abroad and at home are extracted.

Of the springs in Lower Germany, those at *Aix-la-chapelle*, in 8940 parts of water contain 13.06 parts of sulphureted hydrogen gas, 15.25 of carbonate of soda, 6. of carbonate of lime, and 6.21 of muriate of soda. The springs of *Seltzer* in 8949 parts of water contain .435 of oxygen, 13 of carbonic acid, 78.3 of carbonate of lime, and 13.74 of muriate of soda. *Spa* waters in 8933 parts contain 9.8 of carbonic acid, 1.85 of carbonate of soda, and an equal quantity of carbonate of lime.

Of British springs those at *Bristol*, in 10364 parts contain 3 parts of oxygen, 30 of carbonic acid, 13.5 of carbonate of lime, 7.25 of muriate of magnesia, and 11.5 each of the sulphates of soda and lime. The *Cheltenham* waters, in the same quantity of water, contain 30.37 parts of carbonic acid, 15 of azotic gas, 5 of iron, 25.of muriate of magnesia, 480 of sulphate of soda, and 40 of sulphate of lime. *Harrowgate* waters, in the same quantity, contain 8 parts of carbonic acid, 19 of sulphureted hydrogen, 7 of azote, 18.5 of carbonic acid, 615 of muriate of soda, and 91 of muriate of magnesia. The springs at *Kilburn* near London, in 138240 parts, contain 84 of carbonic acid, 36 of sulphureted hydrogen, 3 of carbonate of lime, 13 of muriate of magnesia, 28 of sulphate of soda, and 91 of sulphate of magnesia. The springs at *Moffat* in the south of Scotland, in 103643 parts of water, contain 1 of carbonic acid, 10 of sulphureted hydrogen, 4 of azote, and 4 of muriate of soda.

4. Acids. In the beginning of the preceding section it was stated that when oxygen is combined with other substances the compound sometimes possesses none of the properties of acidity, and is then denominated an *oxyde;* but when these properties are evident the compound is properly called an *acid.* The term acid, which in Latin signifies sour, has been gradually extended to all substances possessing the following properties. 1. When applied to the tongue they excite the sensation of sourness or acidity. 2. They change to red the blue colours

of vegetables. The blues commonly used for this experiment are the tincture of litmus, (a cheap blue paint generally brought from Holland) and syrup of violets or radishes; the flowers of mallows or red cabbage answer very well: these substances are called reagents or tests. If these colours have been previously converted to green by the action of alkalies, the acids restore them to their original blue colour. 3. They unite with water in almost any proportion. 4. They combine with all the alkalies, and with most of the metallic oxydes and earths; forming with them the compounds called *salts,* because in their nature they resemble common sea salt, which is a compound of the muriatic acid with soda an alkali. It is however to be observed that, in order to constitute an acid, it is not necessary that the substance should possess all these properties; but only such as may sufficiently distinguish it from all other bodies.

The acids are by far the most important class of bodies in chemistry: it is by means of them indeed, and by studying their properties, and employing them in examining other bodies; that chemistry has been formed into a science and brought to its present advancement.

All bodies to which the properties of acids have been ascribed are either *products* of combustion, or *supporters* of combustion, or *combustibles.* The acids of the first two classes have only a single base; but those of the third class have usually two or more bases; and they are sometimes destitute of oxygen.

1. The acid *products* hitherto known are only five in number; to which must be added two other acids very closely resembling them, although their composition is still unknown. The following table shows the component parts of the known acid products.

Acids.	Bases.	Oxygen.
Sulphuric Sulphurous	Sulphur	0. 385 0. 15
Phosphoric Phosphorous	Phosphorus	0. 61
Carbonic	Carbon	0. 32
Fluoric Boracic	Unknown	

The acids are here named from their bases, with the exception of the

last two which are named from borax, and fluor spar, the substances in which they are found in the greatest abundance. Hence it appears that in 1 part of sulphuric acid, the oxygen is .385, and the sulphur must be the remainder, or .615. Carbonic acid contains no less than .82 of oxygen, and the remaining .18 must be the carbon.

2. Acid *supporters* of combustion are those substances which are not themselves, strictly speaking, capable of undergoing combustion; but their presence is absolutely necessary, in order that it may take place. The only simple supporter known is oxygen: but when it is united to incombustibles, they also become combustible. The properties of these supporters are that they cannot be produced by combustion;—that they are capable of supporting combustion in other bodies;—and that they are decomposed by exposure to a great heat; their oxygen in that case escaping in the form of gas.

The following table exhibits a view of the principal acid supporters of combustion, their composition, and the proportion of the component parts.

Acids.	Bases.	Proportion of Oxygen.
Nitric	Azote	0. 705
Oxymuriatic	Muriatic acid	0. 16
Hyperoxymuriatic	Muriatic acid	0. 65
Arsenic	Arsenic	0. 346

Of acid supporters of combustion the most important are the nitric and the oxymuriatic. Nitric acid, otherwise called spirit of nitre and *aquafortis*, was known to *Lully*, who was born in the island of Majorca in 1235, who procured it by distilling a mixture of nitre and clay. The same process is still used in large manufactories; but the acid thus obtained being weak and impure, chemists prepare it for their purposes by distilling 3 parts of nitre with 1 of sulphuric acid or oil of vitriol. Pure nitric acid ought to be colourless and transparent like water: it consists of .705 of azote which is its base, and .295 of oxygen.

Muriatic acid, so called as being a component part of sea salt, is commonly prepared by distilling a mixture of 1 part of salt and 7 or 8 parts of clay. Its composition is hitherto unknown; but as it combines with oxygen, it is classed among simple incombustible bodies. This acid when pure is colourless, having a strong pungent smell, and constantly discharging white fumes when exposed to the air. It is commonly however of a pale yellow colour, owing to a small quantity of oxygen with which it is impregnated.

Muriatic acid in the state of gas possesses the invaluable property of neutralizing and correcting putrid particles floating in the atmosphere of rooms, ships, &c. The principal church of *Dijon* in France was so

infected by putrid exhalations, produced by the too common practice of burying within the walls of churches *(a practice that cannot be too severely condemned)* as to be entirely deserted. An eminent chemist of the town poured two pounds of sulphuric acid on six pounds of common salt, contained in a glass vessel, placed on a pan of live coals in the middle of the church, and withdrawing precipitately the door was immediately closed. The muriatic acid gas soon filled the whole building, and was even perceptible through the door. After twelve hours the church was thrown open, and a current of air made to pass through it to carry off the gas; and after some time the noxious putrid odour was completely removed.

That many diseases are fatally contagious, by the action of substances floating in the air, is a truth too well established to require illustration: it has therefore become an object of the utmost importance, to devise proper methods of purifying the air of places where diseases are frequent. The eminent chemist above mentioned, *Guyton de Morveau*, ascertained, by various experiments, that the noxous matter arising from putrid substances, was of a compound nature, and that it might be destroyed by those gaseous bodies or vapours which readily parted with their oxygen. Bodies merely odorous, or of a powerful smell, he found to have no effect: even gun-powder fired in infected air only displaces a part of it; but the remainder is still as fetid as before. Sulphuric acid has no effect: but vinegar diminishes the odour, acting however very slowly and imperfectly. The acetic acid however, that is distilled vinegar as highly concentrated as possible, acts instantly, and completely destroys the fetid odour of infected air. Hence the great utility of the best aromatic vinegar prepared by *Henry* of Manchester. *Dr. Carmichael Smyth* of London received a large parliamentary remuneration for his method of correcting infected air. The directions for this purpose are these. "Fill a pipkin with heated sand; in it sink a tea-cup containing half an ounce of the strongest sulphuric acid, (vitriolic acid, or oil of vitriol) gently heated, and half an ounce of pure nitre in powder. Stir them together with a glass spatula or rod, until a considerable degree of vapour rise from them." The most powerful agent of all, however, is oxymuriatic acid gas, lately introduced and now employed with the greatest success in the British naval and military hospitals.

All that is necessary is to mix together two parts of common salt with one part of the black oxyde of manganese, (glass-maker's soap); to place the mixture in an open vessel in the middle of the infected chamber; and to pour on it two parts of sulphuric acid (oil of vitriol). The fumes of oxymuriatic acid are immediately exhaled, fill the chamber, and completely destroy all infection or contagion.

This oxymuriatic acid gas is of a yellowish green colour: its odour is intolerably acrid and suffocating; and it cannot be breathed without proving fatal. *Pelletier* an ingenious French chemist fell a sacrifice to his experiment on breathing it: a consumption immediately ensued which soon carried him off. Though this substance has been placed among the acids, yet it possesses not a single property characteristic of these bodies. Its taste is not acid but astringent; it does not convert vegetable blues to red, but entirely destroys them, as well as all other vegetable colours; and the colours thus destroyed and turned to white can neither be restored by alkalies nor by acids. It has the same effect on yellow wax. These vegetable colours are destroyed by

the oxymuriatic acid communicating to them its portion of oxygen, by which process it is reduced to the state of simple muriatic acid.

This property has introduced a new mode of bleaching thread, linen, cotton, wax, &c. To show the effect of oxymuriatic acid in bleaching, you may suspend some unbleached calico or linen, moistened with water, in a jar filled with the gas. The natural colour of the cloth will soon begin to fade, and at last totally disappear. If printed cloth of different colours be employed all the colours will be destroyed except yellow. As it removes the stain of common writing ink, but has no power on printer's ink, it is employed to clean old books or prints. Half an ounce of minium (red lead) added to three ounces of muriatic acid will answer this purpose: the acid attracts the oxygen from the minium which is oxyde of lead, and is then converted into oxymuriatic acid, containing about one-fifth part of oxygen and four-fifths of muriate.

3. *Combustible* acids were formerly distinguished into vegetable and animal acids, because almost the whole of them are procured from vegetables and animals. These acids differ from the two foregoing classes in several particulars. When distilled in combination with potasse they are completely decomposed, and charcoal is produced; whereas no combustible substance can be procured by exposing the other acids to heat;——all of them contain at least two simple combustible substances as bases, whereas the others never contain more than one: these two combustibles are always carbon and hydrogen; besides which some of them contain azote, and often oxygen:——they are decomposed by the action of the more powerful acid supporters.

The combustible acids are divided into four orders; the first contains substances which are crystallizable, and may be volatilized by heat without being decomposed. The second order are crystallizable, but cannot be volatilized by heat without decomposition. The third order are not crystallizable; and the fourth order contains three acids, which from their peculiar properties cannot be arranged under either of the other orders. The following table contains the names and component parts of all the acids belonging to these orders.

Order I. Crystallizable, Volatilizable.

Names.	Constituents.
Acetic Benzoic Succinic Camphoric	Carbon, Hydrogen, Oxygen.

Order II. Crystallizable, not Volatilizable.

Oxalic Mellitic Tartaric Citric Sebacic Saclactic Laccic	Carbon, Hydrogen, Oxygen.

Order III. Not Crystallizable.

Malic Lactic Suberic	Carbon, Hydrogen, Oxygen.

Order IV. Anomalous.

Gallic	Carbon, Hydrogen, Oxygen.
Prussic	Carbon, Hydrogen, azote.
Sulphureted Hydrogen	Sulphur, Hydrogen.

The acids of the 1st. order are the *acetic* or vinegar; the *benzoic* from *benzoin*, vulgarly called *benjamin*, an East India resin; the *succinic* drawn from amber; the *camphoric* from camphor, the product of a species of laurel growing in India. Those of the 2d order are the *oxalic*, so called because it exists ready formed in the plant called *oxalis acetosella* or wood-sorrel; the *mellitic*, drawn from a very rare mineral called honey-stone: the *tartaric*, called when pure cream of tartar, being the acid which combined with potasse forms the tartar of wine casks;

the *citric*, drawn from lemons and oranges; the *sebacic* from tallow; the *saclactic*, obtained by treating the sugar of milk with nitric acid; the *laccic* drawn from white lac, a waxy substance produced by insects in India. The acids of the 3d order are the *malic* obtained from apples, and also in great abundance from common house-leek; the *lactic* from milk; the *suberic* from cork. Those of the 4th order which differ from all the others are the *gallic*, drawn from the nut-galls which grow on some species of oak; the *prussic* produced by exposing to a red heat the horns, hoofs, or dried blood of animals, with an equal quantity of fixed alkali or potasse. Hence is obtained a crystallized salt which precipitates metals from their solution in acids. Thus iron dissolved in an acid is thrown down, forming the prussiate of iron, a beautiful blue powder called prussian blue, from the country of the discoverer *Diesbach*, an eminent chemist of Berlin, in the beginning of the last century.

5. Compound combustibles. These are very numerous, consisting almost all of carbon and hydrogen, or of carbon, hydrogen and oxgyen. Those employed in chemistry, as instruments of investigation of the properties of other bodies, are of five sorts, namely, fixed oils, volatile oils, alkohol, ether, and tan, or the tanning principle which has the property of separating glue from its solution with water, and of combining with the skins of animals, and so converting them into leather.

II. *Of secondary compounds.* Many of the primary compounds may be again combined with one another, forming secondary compounds: thus acids combine with alkalies, with earths, and with metallic oxydes, forming compounds called *salts*. The earths combine with the fixed alkalies forming *glass*. The oils combine with alkalies forming *soaps*.

1. The earthy combinations are of the highest utility in common life, and many of the precious stones owe their properties to the same composition. One of the most valuable is *stoneware* taken in the fullest extent of the term. This substance varies in name according to external appearance, the manner in which it is manufactured, and the purposes to which it is applied. Hence we have *porcelane, stoneware, pots, crucibles, bricks, tyles, &c.* all these substances however are formed on the same principles, of nearly the same materials, and they owe their good qualities to the same causes.

These combinations of earths were known from the earliest times. The first building of which we have any account, *the tower of Babel*, founded soon after the deluge, was constructed of bricks formed out of the clay soil of the banks of the Euphrates, and hardened in the powerful sun of that climate. Bricks of the same nature are still used in that country; and those discovered in the heaps of ruins which still point out the situation of the ancient city of *Babylon*, (of which some were lately brought to London and Paris,) have evidently been baked in the suns rays. Stoneware vessels were known to the Jews long before they were carried away into captivity by the Assyrians. Porcelane, or the finest kind of stone-ware was brought to perfection in China and Japan in very remote times; and were even known in Rome before the time of our Saviour, in consequence of the Roman expeditions into Asia. Many attempts were made in Europe in later times to imitate the porcelane of the east: but it was not till about a century ago that a chemist of Saxony in Germany, in trying to discover the best materials for crucibles, accidentally stumbled on a compound that afforded a porcelane similar to the oriental. Hence the celebrity of Saxon or Dresden

china. Since that time the manufactory has been carried to vast perfection, particularly at Sevre near Paris: at Worcester, Derby, and other places of England very fine stoneware is also produced.

Porcelane owes its semitransparency to a kind of semivitrification. The European imitations were composed of materials which easily melted by heat; but the original substance from the east is of a different nature; seeming to consist of two substances, one of which easily melts and incloses the particles of the other when finely powdered, but which are not affected by heat. The ingredients of the China and Japan porcelane are said to be a hard stone called *petunse* which is ground to powder, and a white earth called *kaolin*, which is intimately mixed with the former. The stone is fusible; but the earth cannot be melted when exposed separately to a violent heat.

Stoneware is not formed by mixing together the pure earths, which would be by far too expensive: but combinations as they are found in nature are employed. These combinations must have the following properties:—they must be capable, when reduced to powder, of forming with water a paste sufficiently manageable and adhesive to be shaped in any way required:—this paste, after being exposed to a sufficient heat, or being baked, must acquire such a permanent degree of hardness as to be able to resist the action of the weather and of water:—the vessels formed of it must resist all changes of temperature:—they must resist a strong heat without melting:—they must not be penetrable by liquids, nor liable to be acted upon by chemical agents.

Many of these properties are found in common clay; and it is still used in a variety of ways. Bricks for instance are, or at least always should be, made of clay. Tyles also are made of clay, but of the finer sorts, and usually ground in a mill. Clay is a mixture of alumina and silica: when the first is in too great a proportion the brick contracts and is apt to crack in burning: when this shall happen to be the case, sand which consists chiefly of silica must be added. The red colour of bricks and tyles is produced in burning by the oxyde of iron contained in the clay.

In order that clay be fit for stoneware, it ought to be entirely free from metallic oxydes, which not only discolour the ware, but render it fusible: this last effect is also produced by lime, barytes, &c. To prevent vessels from contracting too much during the process of baking, fine colourless sand must be mixed with the clay. What is called English stoneware consists of tobacco-pipe clay, and powdered flints; Dutch or Delft ware of clay and fine sand; and the coarsest wares of common clay and sand. The materials are ground very fine in a mill, then mixed together and formed into a paste. The different vessels are coarsely moulded on the potter's wheel, and allowed to dry so far as to bear to be handled. After this they receive their due form completely, and when sufficiently dry they are covered with the proper enamel or glazing, and put into the furnace to be baked.

2. *Glass.* Potasse and soda, the fixed alkalies, have a strong affinity for several earths, particularly for silica and alumina, which they dissolve in considerable quantity, especially when assisted by heat. When a strong heat is applied to a mixture of fixed alkali and silica, it melts and forms the transparent body we call *glass*. The knowledge of glass is very ancient. Pliny the Roman naturalist informs us that some merchants, returning with a ship load of soda from Egypt, had

cast anchor in the mouth of the little river *Belus,* (now the *Halou,* falling into the bay of *Acré* on the north side of *Mount Carmel* in *Palestine,*) and had made a fire on the beach to dress their provisions. They carried on shore large pieces of the soda to construct the fire-place and support their kettles. The heat of the fire melted the soda where it rested on the flinty sand, thereby producing glass. For some time the manufacture of this most useful substance was confined to that spot, because its nature was unknown: at last however the ingredients being better observed it was found that, wherever soda and flinty sand could be found, their fusion would always produce glass.

Vessels of pure glass were very highly valued by the ancients; and in the third century panes of glass were employed in windows. They must however have been in use much earlier; for on uncovering the ruins of *Herculanum,* and *Pompeii* near Naples, supposed to have been overwhelmed by the eruptions of Vesuvius about the year 79 of our era, panes of glass were found in the windows, much discoloured, but not destroyed by the hot matter from the volcano. It is however to be observed that, according to some late discoveries, it is probable that those cities were still in existence, and not finally overthrown, until the year 471, when the awful eruption happened which changed the very shape of Vesuvius, and laid waste all the environs.

The materials employed in making glass, are alkalies, earths, and metallic oxydes. Soda is the alkali preferred in this country. Silica is the basis of glass in the state of fine sand or flints; sometimes for very fine glass rock-crystal, (silica crystallized) is employed. Lime renders glass less brittle, and enables it the better to stand the action of the atmosphere; but it ought in no case to exceed the twentieth part of the silica employed, otherwise it corrodes the glass-pots. The metallic oxydes employed are red lead or litharge, and the white oxyde of arsenic; this last is however but seldom used, on account of its poisonous qualities.

After mixing together the alkali and sand it is usual to expose them for some time to a moderate heat: by this operation any combustible bodies in the sand are driven off, and a beginning of combination is brought about, which renders the glass less apt to corrode the clay pots in which it is melted, and the alkali is not driven off, as it would be if at once exposed to a violent heat. This mixture after it is thus heated is called *frit.* It is then placed, while hot, in large pots made of a mixture of pure clay and baked clay, and exposed to a heat sufficiently violent completely to melt the mixture. The scum or *glass-gall* which gathers on the surface is removed; and when the fusion has been brought to the proper point the furnace is allowed to cool a little. In this state the glass is perfectly ductile, and can be formed into any shape that may be required.

When the fusion is complete the workman dips the end of an iron tube in the fluid, turning it about until a sufficient quantity adhere to it: this he then rolls gently on an iron plate to render the substance more compact. He then blows through the tube, causing the melted glass to swell out into a hollow ball. If a common *bottle* be wanted this ball is placed in a proper mold, and blown up till it exactly fill it; and the neck is formed on the outside of the mold by drawing out the ductile glass. *Window glass* is blown into a cylindrical shape which being cut open is gradually bent back to a flat plate.

Large plate glass for mirrors, &c. is made by pouring the liquid matter over a horizontal metallic table, with raised ledges, along which a roller is passed, to reduce the plate of glass to an uniform thickness.

Flint-glass commonly but erroneously called *crystal,* is the densest, the most transparent, colourless, and beautiful. The best kind manufactured in London, is said to consist of 120 parts of white silicious sand, 40 parts of pearl ash, 35 of red oxyde of lead, 13 of nitrate of pot ash, and 25 of black oxyde of manganese. Flint-glass is the most fusible of all: it is used for decanters or other vessels intended to be cut or polished, for lustres, chandeliers, &c. and the lenses of the best telescopes are made of flint-glass. What is called *crown-glass,* consists of soda and fine sand without lead: *bottle-glass,* the coarsest and the least fusible of all is made of the refuse of soap-boilers, and common sand; its greenish colour is owing to iron. According to experiments, flint-glass melts at the temperature of 19° of Wedgewood's scale, crown-glass at 30°, and bottle-glass at 47°.

Glass is tinged of different colours by different metallic oxydes; blue by cobalt, green by iron or copper, violet by manganese, red by a mixture of copper and iron, purple by gold, white by arsenic and zinc, yellow by silver and by combustible bodies.

Though glass when cold is brittle, yet while liquid it is one of the most ductile bodies known. If a thread of melted glass be drawn out and fastened to a reel, the whole of the glass may be spun off, so fine as to be scarcely visible by the naked eye.

It is one of the invaluable properties of glass, that it is acted upon by very few chemical agents. The fluoric acid, drawn from Derbyshire spar, dissolves it very rapidly: so do the fixed alkalies when assisted by heat: even hot water, by long continued action, dissolves a little of it. The fluoric acid is employed to engrave upon glass. The surface of the glass is covered with a thin coat of bleached bees-wax, and the figures, inscription, &c. drawn on it as in etching on copper. Then put the spar finely pounded into a leaden vessel, pouring sulphuric acid over it. Place the glass with the etched side downwards over the vessel two or three inches from it. Apply a gentle heat to the vessel, which will make the acid act upon the spar, which will disengage the gas to act upon the glass, corroding it to the degree required. The wax is afterwards removed by oil of turpentine.

If glass vessels were rapidly cooled when first made they would contract unequally according to their unequal thickness; they would consequently either crack or become so brittle as to fall to pieces when handled. To prevent this inconvenience the vessels are placed in a large red-hot furnace, which is allowed to burn out and cool very slowly to the temperature of the air. By this process called *annealing* glass is rendered strong and capable of enduring considerable pressure and variations of heat and cold.

3. Salts. The term *salt* was originally confined to common kitchen salt or muriate of soda, a substance known from the remotest ages. In after times the term became general, and was employed by chemists in a very extended and not very definite sense. Every body which has a taste, is easily melted in water, and is not combustible, has been called a salt. At present however a salt is a compound of an acid with an alkali, an earth, or a metallic oxyde. Salts are now denominated from the acids they contain; and the alkali, earth, or oxyde combined with

the acid is called the *base.* Thus common salt being a compound of the muriatic acid and soda is called the *muriate of soda,* and soda is the *base* of common salt. When an acid combines with two bases at once it forms a triple salt. The number of salts now known amounts perhaps to near 2000: and it may give some idea of the rapid progress of this branch of chemistry to consider that 50 years ago not more than 30 salts in all were properly known.

As the different salts are denominated from their acids, the kinds must be as numerous as the acids; and their names express the nature of the acid. When the acid contains the maximum, that is as much as possible of oxygen, the name ends in *ate;* but when it contains a smaller quantity of oxygen the name ends in *ite.* Thus salts containing sulphuric acid, that is, sulphur with the greatest possible quantity of oxygen, are called *sulphates,* and those containing a smaller quantity of oxygen and sulphur, or sulphurous acid are *sulphites.* Every particular salt is distinguished by subjoining to the generic term the name of its base; thus the salt composed of sulphuric acid and soda is called the sulphate of soda; and triple salts have the names of both bases; thus the salt compounded of tartaric acid with potasse and soda is called the tartrate of potass and soda.

The salts are naturally divided into two grand classes, the first comprehending the alkaline and earthy salts, which derive their most important characters from their acids, and the second class comprehending the metalline salts, which on the contrary draw their most important properties from their bases. The alkaline and earthy salts are further subdivided into combustible and incombustible.

To enter on any detailed account of the various kinds of salts would correspond with neither the limits nor the objects of this work: it will therefore be necessary to confine our observations to a few of those which are of the greatest importance in ordinary life.

Common or table salt. This salt, which has given a name to all other similar compounds, is now in modern chemistry called *muriate of soda,* from the word *muria,* which in Greek and Latin signifies any thing salt or salted. This salt exists native in great abundance; immense masses of it are found in different countries, requiring only to be dug out and reduced to powder. At Cardona in the north east quarter of Spain is a little hill 500 feet high consisting wholly of salt. In this state it is called rock-salt. The waters of the ocean also contain a great proportion of this salt, to which they owe their taste, and their power of resisting congelation, until cooled down to $28\frac{1}{2}°$, whereas fresh water freezes at $32°$. When sea water is sufficiently evaporated by boiling, the salt precipitates in crystals. In this way salt is obtained in this country. But the common salt is not pure enough for chemical uses, containing generally muriate of lime, (fixed ammonia,) &c. it may however be purified in this way. Dissolve the common salt in four times its weight of pure water, and filter the solution. Drop into it a solution first of muriate of barytes, then of carbonate of soda, (soda,) as long as any precipitate falls. Separate the precipitates by filtration, and evaporate slowly till the salt crystallizes. Pure salt is not affected by exposure to the air; but common salt contains often a little muriate of magnesia which disposes it to attract moisture from the air, and so to melt. According to the latest experiments salt when pure consists of nearly 39 parts of muriatic acid, 53 of soda, and 8 of water.

The uses of salt are equally numerous and important. It is the common and most useful seasoner of food; it preserves meat from putrefaction, and butter from rancidity; it serves for an enamel to the surfaces of coarse earthenware; it is an ingredient in many processes in dyeing; it is employed in assaying metals: its utility in chemistry is very extensive; from it alone muriatic and oxymuriatic acids can be obtained; and from it great quantities of soda are now extracted, instead of the soda formerly obtained from the burning of vegetables. The value of salt in agriculture is well known; and it forms an important ingredient in the blood, and some other juices of animals.

Salt, or the muriate of soda, is commonly obtained from sea-water or from salt springs in the following way, in different parts of England and Scotland.

Close to the sea side a bason or pond is inclosed, by taking advantage of the natural rocks, or by a wall so high as to exclude the tide and waves. Into this pond or bason (called a *sump* or *bucket-pot* in different places,) the sea water is received at a sluice-gate, or by a pump. Standing there for some time the watery parts evaporate, and the remainder is much salter than before. Adjoining to the sump is constructed the saltern or salt-pan, a long low building divided into parts by a wall. That farthest from the water, or the *fire-house*, contains the entrance of the furnace and the fuel, affording cover also for the workmen or salters: the other division is the *pan-house* or *boiling-house* containing the pan in which the salt water is boiled, under which is the furnace or fire-place.

The boiling pan is of an oblong form flat and level in the bottom, and inclosed by perpendicular sides: the length in general about 15 feet, the breadth 12 feet, and the depth 16 inches. The pan is formed of broad plates of hammered iron, joined together with nails, and the joinings filled with cement; across the edges are laid strong iron beams, from which hang a number of hooks connected with the bottom, by which it is supported against its own weight, and that of the water. The four corners of the pan rest upon brick or stone pillars, and the other parts upon thick iron pillars; all resting on the floor of the furnace below, in the middle of which the fire is placed; but the flame and heat spread all over the bottom of the pan.

When the pan is properly filled with sea-water by pumping from the bason, and is beginning to grow warm, the workman beats up the whites of three or four eggs in as many gallons of salt water, which he pours into the pan and mixes with a rake. Instead of eggs, bullock's or any other blood may be used. This is to clarify the water; and when it boils a frothy black scum collects, and is taken off, leaving the water perfectly clear and transparent, which is then briskly boiled till much of the watery part is driven off, and the remainder in the pan becomes a very strong brine. Small crystals of salt now begin to shoot across the surface of the brine, which in such a pan as is thus described generally happens in 5 hours boiling. The pan is again filled with water, and a second clarification, evaporation, and crystallization take place: this is repeated twice or thrice over; and when the crystals are forming, the fire is slackened, only such a fire being kept up as to keep the brine simmering. The complete granulation of four pans filled in this way requires 9 or 10 hours. The salt is now drawn up in heaps at the sides of the pan, where it drains for some time, and is then taken

out and placed on proper vessels and frames till all the moisture be entirely drawn off, and the salt be fit to be removed to the store-house, where it is immediately put under the charge of the officers of the excise.

In the corners of the pan are placed small vessels into which are collected the *scratch*, or the calcareous substances separated from the salt in boiling. The liquor remaining uncrystallized in the pan contains a great proportion of *bittern,* that is sulphate of magnesia or Epsom salts, from which magnesia is usually obtained, by adding potasse which unites with the sulphuric acid, and disengages the magnesia.

Salt is procured from the water of salt springs by a similar process: but in warm climates the sea-water is drawn into shallow basons where the water is evaporated by the heat of the sun, and the salt crystallizes without any preparation. This salt is however very impure, and requires to be again dissolved, clarified, and again crystallized.

The *muriate of ammonia,* formerly called *sal ammoniac,* was brought from Egypt, where the greater part of the fuel consists of the dung of cattle dried. This substance contains the muriates of soda and ammonia ready formed. The soot arising from this fuel is collected and put into large glass bottles which are then exposed in furnaces to a strong heat. The sal ammoniac gradually sublimes, and attaches itself to the upper part of the bottles, where it forms a cake of some inches in diameter. The first manufactory of this salt in Europe was opened in Germany by *Gravenhorst* in 1759; soon after which it was made in France by *Beaumé*, and in Scotland by *Hutton.*

This salt is applied to various purposes: it is from it that pure ammonia is extracted: a considerable portion is consumed by the dyers, and perhaps a still greater quantity by the coppersmiths, to prevent the oxydation of the metals they cover with tin. Its use in medicine, particularly in reviving persons exposed to fainting, and nervous attacks, is well known.

Borax is supposed to have been known to the ancients under the name of *chrysocolla :* it is a sub-borate of soda, that is the soda which is its base is not completely saturated with the boracic acid. Borax is brought from India in an impure state under the name of *tinkal.* Borax is sometimes used in medicine as an astringent: it also serves to promote the fusion of metals, whence it is called a *flux :* it enters also into the composition of some of the coloured glass pastes made in imitation of precious stones; but its great use is to promote the soldering of gold and silver.

Sulphate of barytes or *ponderous spar,* contains in its native state 13 parts of sulphuric acid, 84 of barytes, and 3 of water. When formed into a thin cake with flour and water, and heated to redness, it gives out light in the dark. Of this nature is the Bolognian stone or phosphorus.

Sulphate of soda was first discovered by a German physician, and was from his name called *Glauber's salts ;* but he called it *sal mirabile ;* it contains 27 parts of sulphuric acid, 15 of soda, and 58 of water.

Sulphate of lime. The common sort was formerly called *gypsum,* and sometimes *selenite,* as resembling the moon in colour; it is now commonly called plaster of Paris. When heated it loses its water of crystallization and falls into a soft white powder, which, when all its water is driven off by a red heat, absorbs water very rapidly and renders it solid,

at the same time that its heat increases; so that if formed into a paste with water, it hardens and dries very quickly.

Sulphate of magnesia was first observed in the springs at Epsom by *Dr. Grew* in 1675: but *Dr. Black* first examined its properties; for before his time, it was confounded with sulphate of soda or Glauber's salts. Epsom salts abound in sea water; and the uncrystallized liquor remaining in salt pans, after the crystallization of common salt, called *bittern,* consists almost entirely of this salt, which contains in crystals $29\frac{1}{3}$ parts of sulphuric acid, 17 of magnesia, and $53\frac{2}{3}$ of water; but in the dry state $63\frac{1}{3}$ parts of acid, and $36\frac{2}{3}$ of soda. This salt is employed as a purgative: but its great use is to afford magnesia. The salt is dissolved in water, and half its weight of potasse being added, the acid unites with it, and the magnesia falls to the bottom, which is then purified by washing in water and dried.

Alum is now known to be a compound of sulphuric acid with alumina and potasse in different proportions. It was brought into Europe from the east till the 15th century, when it was manufactured in Italy, and in Elizabeth's reign it was first made in England. When exposed to a strong heat it swells and foams, losing almost half its weight, and the remainder is calcined or burnt alum, sometimes used as a corrosive. In its crystallized state alum contains $17\frac{2}{3}$ parts of sulphuric acid, 17 of its proper base, and $70\frac{1}{3}$ of water: but when burnt $36\frac{1}{4}$ parts of acid, and $63\frac{3}{4}$ of base. Alum is of great use as a mordant or biter in dyeing; it is also of service in the preparation of leather, and is employed by calico-printers, engravers, &c. not to mention its use in medicine, in preserving animal substances from corruption, and its peculiarly valuable property of preventing wood from catching fire. If three parts of alum, and one part of flour or sugar be melted together in an iron ladle, and the mixture be dried till it become blackish and cease to swell; if it be then pounded small and put into a glass phial placed in a sand-bath, till a blue flame issue from the mouth of the phial, and after burning for a minute or two be allowed to cool; a substance is obtained called from the discoverer *Homberg's* pyrophorus, which has the useful but very hazardous property of catching fire whenever it is exposed to the air, especially if the air be moist.

Phosphate of lime is the basis of the bones of all animals, and from it almost all the phosphorus of the chemists is extracted: it is employed in the cure of the rickets, and in making cupels for refining metals. It consists of 41 parts of phosphoric acid, and 59 of lime.

Carbonate of lime exists in great abundance in nature under the names of marble, chalk, limestone, &c. its component parts when crystallized are 45 of carbonic acid, and 55 of lime, or rather 50 of acid and water with 50 of lime.

Carbonate of potasse or fixed alkali, salt of tartar, &c. contains 43 parts of acid 41 of potasse and 16 of water. The potasse of commerce contains always a smaller proportion of acid; but this varies according to the materials of which it is made.

Carbonate of soda, barilla, or soda, is usually obtained by burning and lixiviating marine plants, or by decomposing common salt. It usually contains when crystallized $14\frac{1}{2}$ parts of carbonic acid, $21\frac{1}{2}$ of soda, and 64 of water; but when dry it consists of 40 parts of acid, and 60 of soda.

Nitrate of potasse otherwise called *nitre* and *saltpetre,* (stone-salt) is

naturally produced in many countries; and its continual reproduction in places from which it had been extracted, has greatly excited the attention of naturalists. It is now known that to produce this salt nothing else is necessary, but a basis of lime with heat, and an open but not too free communication with the dry atmospheric air. When these circumstances are combined the acid is formed, and afterwards the alkali makes its appearance.

Nitre or saltpetre is obtained artificially from the refuse of animal and vegetable bodies undergoing putrefaction, and mixed with calcareous and other earths. The nitre is extracted from the beds of these materials by steeping them in water, which when fully impregnated is evaporated by heat, and a brown salt remains, but mixed with other salts, which being more soluble than itself, are separated from it by repeated washings in water. Nitre consists of 44 parts of acid, 52 of potasse, and 4 of water.

One of the most important compounds into which nitre enters is *gunpowder*, the introduction of which has completely changed the art of war. The original discoverer of gun-powder, and the person who first thought of applying it to war, are equally unknown. It was however certainly employed in the 14th century. From certain records in Germany, it appears that cannon were used in that country before the year 1372. It is also said to have been used by the Moors in Spain as early as 1334; and our Edward the 3d had four pieces of cannon at the battle of Cressy in France in 1346. It is probable however that gunpowder was known to the Chinese at a much earlier period.

Gunpowder is composed of 76 parts of nitre, 15 of charcoal, and 9 of sulphur. The ingredients are first reduced separately to a fine powder, then intimately mixed and formed into a thick paste with water. When this has dried a little it is placed upon a kind of sieve full of small holes through which it is forced. By this process the substance is divided into small grains which when dry are put into barrels which are made to turn round on their axis. By this motion the grains rub against each other, their roughnesses are worn off, and their surfaces smoothed: the powder is then said to be glazed. Gunpowder explodes violently when a red heat is applied to it. This combustion takes place even in a vessel entirely deprived of its air: a vast quantity of gas is emitted, the sudden production of which is the cause of all the violent effects which this substance produces. This combustion is owing to the decomposition of the nitre by the charcoal and sulphur. By the explosion no sensible quantity of water is produced; but the substances remaining behind soon attract moisture, and the sulphur enables them to act strongly on metallic bodies.

Tartrate of Potasse exists in two varieties; the first containing an excess of acid is usually called *tartar;* the second which is neutral was formerly called soluble tartar, because it dissolves in water much more readily than the other. The first sort which is a supertartrate of potasse, is found, in an impure state, incrusted on the bottom and sides of casks in which wine has been kept. It is afterwards purified by dissolving it in boiling water, and filtring it while hot. On cooling it deposites the pure salt, in very irregular crystals commonly called *crystals* or *cream of tartar*, containing 57 parts of tartaric acid, 33 of potasse, and 7 or 8 of water.

Metalline salts. The action of the acids on metals, and the saline

bodies formed by their combination, were some of the first objects to which the earliest chemists directed their attention. The facility with which some of these compounds change their state, the activity and corrosive nature of many of them, the permanency of others, and the apparent conversion of one metallic salt into another; these and some other peculiarities in metalline salts were well calculated to excite attention and exercise ingenuity.

The difference between the oxydes of the same metal consists in the proportion of oxygen which they contain. Now in general oxydes which do not contain all the oxygen they are capable of holding, have a tendency to absorb it, until they be completely saturated. This tendency shows itself with the greatest energy, when the oxydes are combined with acids, and in a state of solution. Hence green vitriol is a salt compound of sulphuric acid, and black oxyde of iron. When dissolved in water, and exposed to the air, it soon absorbs oxygen; the black oxyde is thereby changed to the red, and a new salt is formed, consisting of sulphuric acid and red oxyde of iron. This change is exactly the reverse of that which happens to those earthy and alkaline salts which contain an acid with the least possible quantity of oxygen. They indeed absorb oxygen, and are changed into other salts: but the oxygen in them combines with the acid, while in the metalline salt it combines with the base. These different earthy and alkaline salts have been very happily distinguished by the different terminations of their names. Thus sulph*ite* of potasse contains the acid of sulphur, with the smallest possible quantity of oxygen, and the sulph*ate* of potasse contains the same acid, with the greatest possible quantity of oxygen. Some of the most important of the salts formed by the action of acids on metallic bodies, were already mentioned in speaking of the several metals, to which passages the reader is referred.

4. Soaps. This term in Latin *sapo*, and in Greek *sapôn*, first occurs in the writings of Pliny and Galen, to express a detergent or substance for cleaning cloth of various sorts. Pliny attributes the invention of soap to the ancient Gauls, observing that it was composed of tallow and ashes; adding however, that the German soap was esteemed the best.

The fixed oils have the property of combining with the alkalies, earths, and metallic oxydes, forming with them the compounds called soaps, differing from one another very materially, according to the nature of their base. Soaps are also distinguished into hard and soft, the first made of soda, and the last of potasse.

Hard or soda soap is prepared in this way. A quantity of common soda is pounded and mixed in a wooden vessel with a fifth part of its weight of lime, slacked, and passed through a sieve just before it is used. Upon this mixture water is poured considerably more than is required to cover it, and allowed to remain for several hours. The lime attracts the carbonic acid from the soda, and the water is impregnated with the pure alkali; it is then drawn off by a stop-cock in the vessel, and called the *first ley*. Another portion of water is then poured on the soda, which after some hours is also drawn off and called the *second ley*. In the same way water is again poured on and drawn off, forming the *third ley*. A quantity of oil equal to six times the weight of the soda used is then put into the boiler, together with a portion of the third or weakest ley; and the mixture is kept boiling, and agitated with a wooden instrument. When all this ley is consumed the second

is used; the oil becomes milky, combines with the soda, and after some hours begins to thicken. Portions of the first or strongest ley are then added from time to time, the substance being continually agitated, and at last the soapy matter begins to separate from the watery matter. A quantity of common salt is now added, to render this separation the more complete: the boiling is still continued for some hours, when the fire is withdrawn, and the contents of the boiler are suffered to remain without disturbance. The soap then swims on the top of the liquor which is drawn off, and preserved for farther use, as it contains carbonate of soda, or common soda. The fire is then rekindled, and a little of the first ley added to the soap to promote its melting. By repeating this operation, the soap is brought to a proper consistence, and then poured into vessels to cool; in a few days it is fit to be taken out and formed into cakes.

Olive oil is found to answer best for making hard soap, and next to it is tallow. Linseed and whale oils are only proper for soft soap.

Water has often been combined with tallow soap, for the purposes of fraud, because it increases the weight, but adds nothing to the value of the soap. But this fraud may be detected by allowing the soap to lie for some time exposed to the air. Soap fit for sale contains about 61 parts of oil, $8\frac{1}{2}$ of alkali, and $30\frac{1}{2}$ of water. White soap is made of tallow and soda; but when rosin is mixed with the tallow, yellow soap is produced.

Soft or potasse soap is made in the same way with the hard, but when potasse is used, the soap never becomes solid or hard. In this country it is made of whale oil, and sometimes a little tallow is added, which appears in fine white spots.

Soap has also been made of wool in place of oil. The ley is formed as before, and when boiling hot shreds of woollen cloth are thrown into it, where they are speedily dissolved. A proposal was also made lately to use muscles of fish in the room of tallow or oil; but experiments have shown this project not to answer.

Soaps made of oils and earths instead of alkalies are insoluble in water, and incapable of being used in washing. They are readily formed by mixing common soap with a solution of any earthy salt: the alkali of the soap combines with the acid of the salt, while the earth and oil unite to form an earthy soap. Hence the reason why waters holding in solution an earthy salt are unfit for washing. They decompose common alkaline soaps, and form an earthy soap insoluble in water; hence they are called *hard waters*.

Metallic oxydes may be combined with oils in two ways; by mixing a solution of common soap with a metallic salt, forming a *metallic soap*, and by uniting the oxyde directly with the oil, in which state the mixture is called a *plaster*, to be spread on cloth, leather, &c. for use in surgery.

Third. Of Affinity.

All the great bodies constituting the system of which our earth is a part, and of which the sun is the centre, are urged towards each other by a force which preserves them in their orbits, and regulates all their motions. This force we call *attraction* as if the bodies were mutually *drawn* towards one another; of its nature however we are entirely

ignorant; whether it be inherent in these bodies themselves, or the consequence of some external agent, are questions beyond the reach of our philosophy. It is however apparently more simple, and therefore more agreeable to the operations of nature in other cases, to suppose the cause which disposes bodies to attract one another to exist within them, than the contrary; and for any thing we know it seems to be as suitable to the attributes of the infinite Creator to have bestowed on the heavenly bodies the power of acting on each other at a distance, as the power of being acted on and receiving motion from other substances in contact with them.

Sir Isaac Newton demonstrated, that this attraction of the planets was the same with *gravitation*, or that force by which a heavy body is urged towards the earth; that it exists not only in the planets as whole bodies, but in every component part of them however minute; that it is mutual in its action; that it extends to conlimited distances; and that all bodies, as far as yet known, are possessed of it.

When two bodies are brought within a certain distance of each other, they adhere together, and a considerable force is required to separate them: this is the case with two pieces of polished marble or glass. When a body is dipped in water, and drawn out again, its surface is moistened, that is, part of the water adheres to it. When a piece of gold is dipped in mercury, it comes out stained of a white colour, which cannot be removed, because a portion of the mercury adheres and unites with the gold. In all cases the particles of matter are found united in masses, of endless variety indeed of form and size, but still so intimately connected as to require different degrees of force to separate them.

Attraction is of two sorts, that which acts at sensible distances or which we can measure, and that which acts at insensible distances, or such as are too minute to come within the observation of our senses. To the first sort of attraction belong gravitation or weight, electricity, and magnetism; and to this the term attraction is properly confined. The second sort existing between bodies at insensible distances, and consequently confined to the individual particles is distinguished by the term *affinity*, or close relation. When particles of the same nature are united together the effect is called *cohesion:* but when the surfaces of bodies only are united it is called *adhesion.*

Affinity like sensible attraction varies with the mass and the distance of the bodies: whether cohesion acts in proportion to the mass we cannot know; because we have no way to vary the mass, but by separation of parts, and thereby varying their distance. In the affinity of bodies composed of particles of the same nature two points demand attention, viz. the force by which the particles are kept united, and the form which the particles thus united are known to assume. The force as was before said is called *cohesion,* and the form of the body assumed by the particles in the act of uniting, if that form be regular, is termed *crystal,* and the process in assuming that form is *crystallization.*

1. *Cohesion* varies exceedingly in different substances; but in the same body in equal circumstances it is always the same. Thus a rod of iron is composed of particles cohering so strongly as to require a very great force to tear them asunder. A much smaller force will overcome the cohesion of lead; and a comparatively very small force will separate the particles of chalk. The following table contains a statement of

the cohesive power of several substances, measured by the number of pounds avoirdupois, which, when suspended at the lower end of a rod of each substance an inch square, will be sufficient by their mere weight to tear the rod asunder, in the same way as a thread is torn asunder by a weight, or by pulling it in contrary directions.

Metals.

Steel in bar	135,000	Gold, cast	22,000
Iron, ditto	74,500	Tin, ditto	4,400
Iron, cast	50,100	Zinc	2,600
Copper, ditto	28,600	Antimony	1,000
Silver, ditto	41,500	Lead, cast	860

Alloys.

Copper 6, tin 1	55,000	Gold 2, silver 1	28,000
Brass	51,000	Tin 4, antimony 1	12,000
Gold 5, copper 1	50,000	Tin 3, lead 1	10,200
Silver 5, copper 1	48,500	Tin 8, zinc 1	10,000
Silver 4, tin 1	41,000	Lead 8, zinc 1	4,500

Woods.

Beech, oak,	17,300	Elder	10,000
Alder	13,900	Lemontree	9,250
Elm	13,200	Fir	8,330
Mulberry	12,500	Walnut	8,130
Willow	12,500	Pitchpine	7,656
Ash	12,000	Poplar	5,500
Plumtree	11,800	Cedar	4,880

Bones.

Ivory	16,270	Horn	8,750
Bone	15,250	Whalebone	7,500

From this table it appears that a square bar of steel one inch a side will support the vast weight of 135 thousand pounds or $60\frac{1}{4}$ tuns hanging from it, before it give way and be torn asunder; while an equal bar of common hammered iron supports only 74,500 pounds, not quite 32 tuns, one of cast gold only 22,000 pounds, or not quite 10 tuns, and one of cast lead no more than 860 pounds, not quite 8 hundred weight. It will hence be also seen, that the alloys produced by compounding the metals in different proportions, possess cohesive powers very unlike those of the component metals taken alone. Thus gold which when alone supports a weight of 22,000 pounds will, by mixing it with half its weight of silver, support 28,000; and if combined with only one-fifth of its weight of copper, have its tenacity increased so far as to bear 50,000 pounds, before the rod be torn asunder. The cohesion of copper is doubled by adding one-sixth of tin. Attention to these facts must be of the greatest importance in

various works where the cohesive powers of metals, timber, &c. are called into exercise; powers which can be known from experience alone, and not from any reasoning on the apparent properties of the several substances employed. From experience we learn that the cohesion or tenacity of metals is greatly increased by working them in the forge, and by drawing them out into wire. By this last operation, gold, silver, and brass have their cohesion nearly tripled; and copper and iron have theirs more than doubled.

When a solid body is immersed in a liquid, if the particles of the liquid attract those of the solid more forcibly than the particles of the solid attract one another, these last are gradually carried off by the fluid, and combine with its particles; the solid is then said to be *dissolved*, for the bond of union between its particles is broken. Thus sugar is dissolved by water, and sulphur by oil. When the particles of the fluid have attracted so many of those of the solid as that the attraction of the remaining parts of the solid balances that of the fluid, the solution is stopt, and the liquid is said to be saturated. Let now a part of the liquid be withdrawn, and the attraction of the remainder for the dissolved particles of the solid must be weaker than that of the solid particles for each other: these last will therefore have a tendency to quit the liquid, and to reunite together, forming again a solid body; and if the whole of the liquid be gradually withdrawn the whole of the dissolved particles will again unite into a solid body: this is called *crystallization*.

2. *Crystallization.* The term *crystal* originally signified in the Greek *ice*, being composed of two words expressing to be contracted, and rendered solid by cold. From ice or frozen water the term came to be applied to other substances resembling ice, particularly to transparent quartz or silica, usually found in clefts of rocky mountains, and thence called *rock-crystal.* The same term is also applied to the finest transparent glass, when cut into different forms for use. Rock-crystal itself was, by the ancients, supposed to be nothing but water congealed by cold. In the present times by crystals we mean all those regular figures which bodies assume, when their particles have full liberty to combine, agreeably to the laws of cohesion. These regular bodies occur very frequently in the mineral kingdom, and have long attracted attention on account of their singular beauty and regularity. Thus the diamond is crystallized carbon, the substance which when combined with oxygen forms charcoal. The brilliant red ruby, the yellow topaze, the blue sapphire, the purple amethyst, are generally found as crystals of alumina (the base of clay,) with very small proportions of silica and iron. From these crystals however, diamond essentially differs in being altogether combustible.

By far the greater number of salts likewise assume a crystalline orm; and as they are almost all soluble in water we can obtain their crystals at pleasure. In general every individual substance puts on in crystallizing a particular form, or a certain set of forms, by which each may be easily known. Thus common salt assumes the form of a cube; alum that of two four-sided pyramids joined at their bases; saltpetre a six-sided prism; sulphate of magnesia, (Epsom salts,) a four-sided prism; carbonate of lime (marble, limestone, &c.) is often found crystallized in the form of a rhomboid.

As the particles of bodies must be at liberty to move before they can crystallize, they must first be made fluid by either solution in a liquid

or fusion by heat. Solution in a liquid is the common method of crystallizing salts: they are dissolved in water; the water is slowly evaporated, the saline particles are thus brought nearer to each other, at last they combine by their mutual attraction, and form crystals which, becoming gradually larger by the accession of new particles, in the end fall down to the bottom of the vessel.

Some salts are soluble only in a small quantity when cold water is applied to them, but in a much greater quantity in hot water; that is to say water at the ordinary temperature has little effect on them, but water combined with caloric dissolves them readily. When hot water thus saturated with salts again becomes cold it is no longer capable of holding them all in solution; the consequence is that the saline particles gradually approach each other and crystallize. Sulphate of soda, (Glauber's salts,) is a salt of this kind; and the experiment may be easily tried. To crystallize such salts nothing more is necessary than to dissolve as much of them in hot water as it will receive, and then allow the mixture to cool by degrees. The quantity of salts exceeding what the water when cold can retain in solution will fall crystallized to the bottom. Were we to attempt to crystallize this mixture by evaporating the hot water we should not succeed; nothing would be procured but a shapeless mass of salt. In the same manner sugar is dissolved in water. At the temperature of 48°, (about that of London in March and October,) water dissolves its own weight of sugar: and its dissolving power increases with the temperature. Water thus saturated with sugar is called syrup, and when made very strong, and allowed to cool very slowly, the sugar it contains crystallizes and falls to the bottom of the vessel, in the form of four-sided or six-sided prisms, terminated by two-sided or three-sided summits. There are however other salts nearly equally soluble in cold and in hot water; common salt for instance. Such salts cannot therefore be crystallized by cooling; but they may be crystallized by evaporating the water while hot: these salts of course contain but little water of crystallization.

Many substances exist which are insoluble in water or any other liquids, but which are capable of assuming a crystalline form: this is the case with the metals, with glass, and with some other bodies. To crystallize these substances we employ fusion, which is only a solution by the application of heat; a process recognized even in common language; for we speak equally of melting sugar in water, and melting lead on the fire. By fusion of metals the particles are separated from each other; and if the cooling go on slowly they will arrange themselves in regular crystals.

All watery fluids are contracted by cold, until it arrive at a point 7 or 8 degrees above their freezing point, when they begin again to expand at nearly the same rate with their previous contraction; and provided they be suffered to remain perfectly still without the least motion or agitation, they may be cooled down in a state of fluidity much below their freezing point. Thus water when perfectly still may be cooled down to 10° of Fahrenheit: but if it be quickly agitated, especially if a small particle of ice or snow be dropped into it, a part of the water will instantly congeal, and the temperature will at once rise up to 32°, in consequence of the heat produced or thrown out on the surface by the act of freezing. If Glauber's salts be dissolved to saturation in hot water, in a phial closely corked up, and allowed to cool without mo-

tion or agitation, no crystals at all are formed: but the instant the phial is uncorked the solution crystallizes rapidly, and the whole in a manner becomes solid. These facts are explained by supposing an affinity between the salt and caloric; so that while they are combined the salt cannot freeze; but that when, by agitating the fluid or uncorking the phial, a communication is opened with the atmosphere, which is a powerful conductor of heat, the caloric is rapidly carried off, and the liquids instantly congeal or crystallize.

Having thus in a very summary way pointed out some of the most interesting phenomena, comprehended in the very extensive and important study of chemistry, the subject will now be closed by a few remarks relative to a peculiar production of nature which, of late years, has greatly and deservedly attracted the attention of chemical philosophers.

Luminous bodies called *fire-balls, meteors,* &c. have in all ages been observed in the heavens. Their disappearance has frequently been accompanied by a loud explosion like a clap of thunder, and it has been often affirmed, that heavy stony bodies fell from them to the earth: these have been vulgarly called thunderbolts, on the supposition of their being produced during storms of lightning and thunder, or by the firy meteors seen passing rapidly across the air. One of the most remarkable of these meteors appeared in the western parts of Europe on the 18th of August 1783. It appeared about 9 in the evening, and was very luminous: it was seen all over Britain from north to south, and over a great part of the continent: it moved with very great velocity, and from observations made at various places, its elevation above the earth must have been nearly 60 miles; consequently from its apparent magnitude it must have been at least a thousand yards in diameter.

It is only twenty years since proper a tention was bestowed on the stony substances affirmed to have fallen from the atmosphere. A collection of instances supported by unquestionable evidence was published in 1796 by *Mr. Edward King* of the Royal Society of London; and in the Philosophical Transactions for 1802 appeared a dissertation by *Mr. Howard* on the subject, adducing irresistible proofs that the stones he had procured and examined had actually fallen from the atmosphere. Mr. Howard by accurate chemical examination of various specimens of these stones, discovered that they completely differed from every other kind of stone hitherto known; that they all resembled one another, and were all composed of the same ingredients, from whatever part of the world they were brought; for he analyzed specimens collected not only in this country, but in France, Germany, Italy, and even in India. It is therefore quite inconceivable that, in climates and soils so different in nature, stony bodies should be found in detached masses, precisely similar in every respect, but totally differing from every other mineral of the countries where they were found, unless they all proceeded from the same origin.

Most of the stones that have been observed to fall from the atmosphere have followed the appearance of luminous bodies or meteors,

which burst with an explosion, and then the stones fell to the ground. Sometimes the stones continue luminous till they sink into the earth; but most commonly their light disappears at the time of the explosion. These stony bodies when found after an explosion, or being observed to fall, have always been hot, and often smell strongly of sulphur. They are of all sizes from a few ounces to several tons in weight, usually roundish with a black crust, consisting chiefly of iron oxydized. From the velocity and height with which they come down, they commonly bury themselves some depth under the surface. Their outer surface is rough, and when broken the inside is of an ash grey colour, grained like coarse sandstone. When examined with a microscope four different substances are perceived, namely a number of round bodies, some as large as peas, so hard as to scratch glass; fragments of pyrites, (sulphuret of iron;) grains of metallic iron, and a soft earthy substance in which the three other bodies are cemented together. The outward black crust consists of iron and nickel compounded, partly metallic, and partly oxydized. The pyrites contain iron, nickel, and sulphur. The metallic grains are iron and nickel; and the small yellow round bodies consist of silica, magnesia, iron and nickel.

Various origins have been ascribed to these extraordinary substances; some have supposed them to have been thrown up to a vast height in the air by volcanoes, and then carried to a distance by the winds: but no such substances are ever found among the productions of volcanos. Others, among whom is even the celebrated French astronomer *La Place*, have imagined them to have been projected from the volcanos known to exist in the moon, with such force as to come within the sphere of the attraction of the earth, and so be drawn to its surface. But the opinion which seems to be the most rational is, that these metallic concretions are actually formed by chemical combinations in our own atmosphere, and thrown upon the earth by the explosion of meteors.

Not only these stony concretions are found in various parts, always containing iron in different states, but masses of native iron itself have been discovered in various parts, mixed with nickel, and exactly resembling the iron found in atmospheric stones. These metallic masses must therefore be ascribed to the same origin; for it is well known that real native iron, as it is found in the bowels of the earth, is totally destitute of nickel. Of the masses of native iron the most remarkable have been found in the midst of the immesne plains in the heart of South America, far from any mountains or other natural sources of such a mineral production. One of these masses that seemed to have been acted upon by fire, was calculated to weigh no less than 13 tons: another, which was 9 feet long by 6 feet broad, and 1 foot thick, would weigh 9½ tons.

Lists have been formed of the best authenticated instances of stones, and what are usually considered to be mineral substances, having fallen from the air; of these a few of the most remarkable are here subjoined. The first column shows the nature of the substances, the second the place where they fell, the third the time when they fell, and the fourth the authority on which the occurrence is founded.

Substances.	Where they fell.	When they fell.	Authorities.
Sulphureous shower - -	Sodom, Gomorrah, &c.	2000 years before Christ	Moses.
Stones - - - - - -	Rome - - - - - -	650 ditto - - - - -	Livy.
Iron - - - - - -	South of Italy - - - -	150 ditto - - - - -	Pliny.
Stones, one of 120 lb. -	North of Italy - - - -	1510 of Christ - - - -	Cardanus.
Stone of 72 lb. - - - -	Macedonia - - - - -	1706 - - - - - - - -	Paul Lucas
Firy shower - - - -	North of France - - -	1717 - - - - - - - -	Geoffroy.
Sulphureous ditto - -	Brunswick - - - - -	1721 - - - - - - - -	Siegesberg.
Stony mass - - - - -	Normandy - - - - -	1750 - - - - - - - -	Lalande
2 stones of 300, & 200 lb.	North of Italy - - - -	1762 - - - - - - - -	Acad. of Bourdeaux.
Stony shower - - - -	South of France - - -	1790 July 24 - - - -	St. Amand, &c.
12 Stones - - - - -	Sienna - - - - - -	1794 July - - - - -	Lord Bristol.
Stone of 56 lb. - - - -	Wold-cottage, Yorkshire	1795 December 13, - -	Capt. Topham.
Stony shower - - - -	India, at Beonares - -	1798 December 19, - -	Mr. Williams
Mass of iron, 70 solid feet	America - - - - - -	1800 April 5, - - - -	Philos Magazine.
Stones from 10 to 17 lb.	Normandy - - - - -	1803 April 26, - - - -	Fourcroy.

Could any doubts be entertained of the great importance of chemistry, considered not abstractedly as a branch of the study of nature, but practically as applicable to the indispensable demands and necessities of human existence, such doubts would be completely removed by a consideration of the following articles, relative to the purification of metals, and the manufacture of bread, wine, beer, &c. &c.

I. *Method of obtaining sundry metals in a state of purity.*

1. *Platinum* can scarcely be obtained perfectly pure in a metallic state, or in any considerable quantity, because we are unable to produce heat sufficient for melting it. The oxyde may however be obtained quite pure from the muriate of platinum, and ammonia. This salt is to be decomposed by a violent heat, and the residuum may be redissolved in nitro-muriatic acid, and precipitated with soda.

2. *Gold* is obtained quite pure by dissolving it in nitro-muriatic acid, and precipitating the metal by dropping in a very diluted solution of sulphate of iron: the powder thus thrown down, when well washed and dried, is pure gold.

3. *Silver.* Dissolve the silver of commerce in nitric acid, and precipitate it with a diluted solution of sulphate of iron, and the powder thrown down will be pure silver. Or precipitate with common salt, form the precipitate into a paste with soda, put it into a crucible lined with soda, and fuse it with a brisk heat: this process will give a lump of pure silver.

4. *Mercury* may be obtained pure by distilling a mixture of two parts of cinnabar, and one part of filings of iron, in an iron retort. The mercury passes over, and the sulphur combining with the iron remains behind.

5. *Copper* is dissolved in muriatic acid, and the metal is precipitated by a polished plate of iron; or the black oxyde of copper, obtained by decomposing cuprated ammonia, may be melted together with an equal weight of pounded glass and pitch.

6. *Iron* can scarcely be obtained perfectly free from carbon, to its combination with which, in different proportions, its various qualities are principally owing.

7. *Tin* may be procured pure by dissolving it in strong nitric acid, when the white oxyde of tin is formed, which is insoluble. This is first digested with muriatic acid, and afterwards with aqua regia. Mix the oxyde thus purified with an equal weight of pitch and a little borax, and melt it in a crucible.

8. *Lead* is purified from the carbonate, by solution in weak nitric acid, and precipitation by zinc, and from the sulphuret, by solution in nitric acid, mixing the solution with muriatic acid and crystallizing. The crystals are dissolved in boiling water, and evaporated to dryness. The mass is melted in a crucible, with $2\frac{1}{2}$ times its weight of black flux, composed of 2 parts of tartar deflagrated with 1 part of nitre.

9. *Zinc* is dissolved in sulphuric acid, and a plate of the metal allowed to remain for a considerable time in the solution. It is then filtered, and the zinc precipitated with soda. When dry the precipitate is mixed with half its weight of pure charcoal, and distilled in an earthen retort, in the neck of which the zinc is collected pure.

10. *Antimony* is dissolved in nitro-muriatic acid, and precipitated by pouring water on it. The precipitate is then mixed with twice its weight of tartar, and fused in a crucible.

11. *Arsenic* in the state of white oxyde is dissolved in muriatic acid, precipitated by water, redissolved, and a plate of zinc is placed in the solution, to which has been added some alcohol. The arsenic is then thrown down in its metallic state.

12. *Manganese* is digested in nitric acid, then mixt with sugar, and dissolved in the same acid. The solution is filtered, and precipitated by an alkali ; mix it into paste with oil, and expose it to a violent heat in a crucible lined with charcoal

II. *Method of making bread, wine, beer, vinegar, &c.*

The most striking distinction between mineral substances and those belonging to the animal and vegetable kingdoms is this, that mineral bodies show little or no tendency to change their nature, and when left to themselves undergo no spontaneous decomposition ; whereas animal and vegetable bodies are continually altering, and when left to themselves always run through a regular course of decomposition. During this spontaneous decomposition of vegetables, it is obvious that their component substances must unite together in a manner different from that in which they were previously united, forming new compounds that did not before exist. It has been observed, that the specific gravity of the new compounds is almost always *less* than that of the old compounds ; some of them usually flying off in the state of gas or vapour. Hence the smell emitted by vegetables in the course of their various changes. When the odour is very offensive or noxious the decomposition is called *putrefaction ;* but when it is not offensive, or when any of the new compounds formed is applicable to useful purposes, it is called *fermentation.* This term alludes to the intestine motion which is always perceptible in vegetable substances while fermenting ; it may also have a reference to the heat generated during fermentation. The term is now often used to express all the spontaneous changes undergone by vegetables, without any regard to the products, in which sense it includes putrefaction.

Fermentation never takes place unless vegetable substances contain

a certain portion of water, and unless they be exposed to a temperature above the freezing point. When quite dry or when frozen, many of them continue long without alteration: hence we have an easy way to prevent fermentation.

Vegetables differ greatly in their tendency to run into fermentation. Sugar, gum, starch, indigo, wax, resins, camphor, wood, cork, &c. though mixed with water, and exposed to heat, show scarcely any tendency to change their nature. Oils absorb oxygen from the air; but too slowly to produce any intestine motion. But it is when several vegetable principles are mixed together, that fermentation is the most perceptible, and the change the most remarkable: and certain substances have a singular efficacy in exciting fermentation in others, on which account they are called *ferments*.

1. *Of Bread.* Simple as the manufacture of bread now appears to us, its discovery must have been the fruit of ages of effort, on the part of men whose sagacity, had they lived in more improved times, would have placed them on a footing with an Aristotle or a Newton.

The method of making bread similar to ours was known in Asia at a very early period. The Jews knew it in the time of Moses; for we find in his book of *Exodus*, a prohibition to use leavened, (that is fermented) bread, in the celebration of the passover. It does not appear however to have been known to Abraham: for in his history we hear frequently of cakes suddenly prepared when wanted, but never of leavened bread. It was therefore probably in Egypt that the Israelites learned the art of fermentation. The Greeks attribute the invention of bread to their Pan, a rural divinity. From Homer we learn that leavened bread was known in the time of the Trojan war, 1200 years before our era. Yet according to Pliny the Romans, highly advanced as they were in political and military skill, were ignorant of fermented bread until 200 years before our era. Since that period the art has never been unknown in the south of Europe: but in some northern parts of the continent fermented bread is, even at this day, very seldom used.

The only substance well adapted for making what we call *loaf-bread* is wheat-flour, which is found to consist of three ingredients, namely, gluten, starch, and a sweet substance possessing some of the properties of sugar. It is to the gluten that wheat-flour owes its superiority over every other flour as the basis of bread. Indeed there are only two other substances known of which loaf-bread can be made, viz. rye and potatoes. The rye-loaf is however by no means so well raised as the wheat-loaf; and potatoes cannot be made into bread at all without a particular management. The potatoes previously boiled, and reduced by rolling to a very fine tough paste, must be mixed with an equal weight of potatoe-starch. This mixture baked in the usual way makes a very white well-raised pleasant bread. Instead of starch barley-meal may be usefully employed.

The baking of bread consists in mixing wheat-flour with water, and forming it into a paste. The average proportion is two parts of water to three of flour: but this varies much according to the age and the quality of the flour. In general the older and the better the flour, the greater the requisite quantity of water. If the paste be allowed to stand for some time, the ingredients act upon one another, and the compound acquires new properties: it gets a disagreeable sour taste, and a quantity of gas, (probably carbonic acid gas) is thrown off; in short the paste

now ferments; and from this process the term fermentation was first applied to chemistry. The gluten is changed by acting on the starch, and no longer can be found. If paste fermented in this way be baked, it forms a loaf full of eyes like our bread, but so sour and unpleasant that it cannot be eaten. If a small quantity of this old paste or *leaven*, be mixed with new made paste, the whole begins to ferment in a short time; a quantity of gas is produced, but the glutinous part of the flour renders the paste so tough, that the gas cannot escape; it therefore causes the paste to swell in every direction; and if it be now baked into loaves, the vast number of air-bubbles confined in every part render the bread quite full of eyes, and extremely light. When the precise quantity of leaven necessary to produce fermentation, and no more, is employed, the bread is light, and free from all unpleasant taste: but if too much be used the taste is bad, and if too little the fermentation does not go on, and the bread is compact and heavy. To make good leavened bread is therefore an operation of some difficulty.

From history we learn that the Gauls, the ancient inhabitants of France, had a different way of fermenting bread. They formed the paste in the usual way, but instead of leaven mixed with it a little of the *barm* or *yeast* which collects on the surface of fermenting beer. This produced as complete a fermentation in the paste as leaven, with the advantage that it was not so apt to spoil the taste of the bread. About 130 years ago, the use of barm was secretly adopted by the bakers of Paris; but when it was discovered the college of physicians there in 1688 declared it to be highly prejudicial to health; and it was not till after a long time that the bakers succeeded in convincing the people, that bread made with barm is superior to bread made with leaven.

The barm as it comes from the beer contains various substances: but gluten mixed with some acid, arising from the vegetables employed to make the beer, are alone essential for fermentation.

When the bread is properly raised, it is put into an oven previously heated. Bakers use no thermometers to ascertain the heat of their ovens; they usually judge of it by flour thrown on the floor, which, if the heat be at the proper point, becomes black very soon without taking fire. From experiments however, it is known that the proper heat of an oven for baking bread is about 448° of Fahrenheit's scale, double the heat of boiling water, and equal to the heat which melts tin.

Bread when taken from the oven is naturally lighter than when put in, from the moisture evaporated by the heat. By accurate experiments a loaf that before baking weighed $4\frac{6}{10}$ pounds, weighed on coming out of the oven only $3\frac{8}{10}$ pounds; so that it had lost in baking $\frac{8}{10}$ pound, or better than 17 per cent. This loss of weight is however by no means uniform; nor can its variation be easily explained. It is clear, that if the paste have not all the same degree of moisture, if the barm or yeast be not accurately and equally mixed through the whole mass, if the fermentation have not equally taken place in every part;—in such circumstances the evaporation must be very unequal. But to perform all this completely must evidently be extremely difficult, and in the common business of the baker must be next to impossible. Great caution is therefore necessary in deciding, from the *weight* of baked bread, whether or not the proper quantity of flour was employed in its manufacture. Upon the whole it has been ascertained that,

other things being equal, the loss of weight occasioned by the heat is proportional to the extent of the surface of the loaf, and to the length of time it remains in the oven. Hence the smaller the surface, or the nearer the figure of the loaf approaches to a globe, the smaller is the loss of weight sustained in baking; and the longer the loaf continues in the oven the greater is the loss.

A loaf that weighed just 4 pounds when taken out of the oven, after the usual baking, was put in again, and after 10 minutes was found to have lost 2 ounces, and in 10 minutes more it lost another ounce. The longer bread is kept the lighter it is, unless it be kept in a damp place, or wrapt round with a wet cloth, which is an excellent method of preserving bread fresh and free from mould, for a long time.

2. *Of Wine.* By the vinous fermentation we mean every species of fermentation which terminates in the formation of an inebriating or intoxicating liquor. These liquors are of two kinds, namely those drawn from the juices of plants, and those from decoctions of seeds; hence come wine and beer.

From a considerable number of ripe fruits a sweet liquor may be expressed, having at the same time a certain degree of acidity. Of such fruits we have in our own country the apple, the pear, the cherry, the gooseberry, the currant, &c.: but by far the most valuable of such fruits is the grape, which grows in abundance in the southern regions of Europe. The grapes producing the most delicately flavoured wines are the growth of moderate climates, such as the fragrant wines of Burgundy in the middle of France; but the richer, and more substantial products of the vine are usually found in the warm regions of the south of Spain, Italy, Greece, &c. In the great and uninterrupted heats of the East and West Indies, however, although grapes are peculiarly delicious for the table, yet it is extremely difficult to make tolerable wine, which in the progress of the manufacture requires at times a temperature considerably lower than what in these climates can often be procured.

The juice expressed from grapes fully ripe is sweet, and called *must* from the Latin *mustum,* a word equally applicable to the first preparation of the decoction of seeds, as the *wort* of beer. The must of wine consists of water, sugar, jelly, gluten, and the acid of tartar, partly saturated with potasse. The quantity of sugar contained in ripe grapes is very considerable: of this we have a proof in the sugar crystallized on the surface of the dried grapes, to which we improperly confine the name of *raisins,* which in the French language signifies the individual fruit, while the *grape* is properly the cluster or bunch of raisins. The sugar may be obtained by evaporating must to the consistence of syrup, separating the tartar, which precipitates during the evaporation, and then setting by the must for some months, during which the crystals of sugar are gradually formed. From a French pint (a quart English) of ordinary must, half an ounce of sugar, and $\frac{1}{10}$ of an ounce of tartar may be extracted: but the very rich muscadine grape will give nearly one-third of its weight of a peculiar kind of sugar.

When must is placed in the temperature of 70°, the ingredients begin to act on each other, and the vinous fermentation begins, showing itself by an intestine motion in the liquid which becomes thick and muddy, the heat increasing, and carbonic acid separating. In a few days the fermentation ceases, the thick part falls down to the bottom,

or rises to the surface, the liquid becomes clear, it has lost its sweetness, and acquired a very different taste, its specific gravity is diminished, and in short it is converted into a totally new liquor, which we call *wine.* This remarkable change is entirely produced by the action of the ingredients of the must, and not by the access of any substance in the atmosphere; for it takes place equally well in close vessels as in the open air.

If the juice of such fruits as contain but little sugar, as currants for instance, be put in a favourable situation, fermentation indeed takes place, but so slowly that the product is not wine but vinegar: if however a sufficient quantity of sugar be mixed with the juice, wine is readily produced. Hence we find that sugar is absolutely necessary to the vinous fermentation, and that without sugar natural or adventitious no wine can be made. It is also remarkable, that in the process the sugar is totally decomposed; for from properly fermented wine, no sugar can be obtained. By the experiments of the most eminent chemists of France, (a country where the art of making wine is more scientifically pursued than any where else in Europe,) it appears that the *strength* of wine is always proportional to the sugar in the must. When the must contains little sugar, the fermentation is rapid, but the wine contains little spirit; and when the proportion of sugar is great, the fermentation is slow, but the product yields a great deal of spirit. The importance of these observations in the manufacture of currant or other wines made in this country, will be obvious to every one.

In fermentation the heat produced is always proportioned to the rapidity of the process; and it seems to be the cause of that rapidity. When the fermentation has ceased, the liquor is put into casks, where the remainder of the sugar is decomposed; after which the wine, decanted off the extractive matter, is put up in bottles for keeping.

Besides water which constitutes a large proportion of all wines, they contain more or less of an acid, alcohol or spirit, extractive matter, volatile oil, and colouring matter. The acid most abundant in wine is the malic or that of apples; but the carbonic acid (fixed air) is also found in several wines, to which they owe their briskness and frothing when poured into a glass. Of this sort is the brisk sparkling wine of *Champagne* in France. Such wines are usually in themselves weak, and they are put up in vessels before the fermentation be over, so that some portion of the carbonic acid is still retained, which escapes when the vessels are opened, producing the briskness by which those wines are distinguished. By adding sugar, (a compound of carbonic acid with oxygen,) to sherry or other mild white wines, a similar brisk sparkling will be produced.

All wines contain more or less of alcohol or spirit, to which they owe their strength. When wine is distilled the alcohol readily separates: and the distillation is usually continued as long as the liquor that comes over is inflammable. The spirit thus obtained is brandy, an abbreviation of the Dutch term *brandewyn,* signifying burnt wine. This liquor cannot be traced in the writings of any ancient nation of the south: among the inhabitants of the northern and colder parts of Europe, however, ardent spirits seem to have been early known. Brandy, as well as rum, and usquebaugh or whisky, consists of water, alcohol or spirit of wine, and a peculiar oil from which proceeds the flavour.

The extractive matter of wine, or the sweet principle, consists of

mucilage, gluten, and extract: but the proportion in the wine diminishes according to its age, being gradually precipitated to the bottom of the cask or bottle.

Every kind of wine is distinguished by a peculiar flavour and odour, probably depending on the presence of a volatile oil belonging to the fruit, but so small in quantity, that it cannot be separated.

The colouring matter of wine is originally contained in the husk of the grape, and is not dissolved till the spirit be developed. When the wine is exposed to the heat of the sun this colouring matter is precipitated: it also sometimes precipitates in old wine; but it may be easily separated by pouring lime water into the wine.

3. *Of Beer.* The method of making beer, although not nearly so simple and obvious as that of making wine, cyder, perry, and other vinous liquors, was certainly known in very remote ages. By the ancient Greek writers the invention of beer is ascribed to the Egyptians, whose country abounded in grain, but was unfit for the culture of the vine. It is however noticeable, that, in the writings of Homer, who flourished a thousand years before our era, and who delights in describing the customs of different nations, no mention is made of beer. Among the northern nations of Europe, the use of beer may be traced back to the earliest periods of their history.

In Europe beer is usually made of barley, in India of rice, in the interior of Africa, the heroic but ill-fated traveller *Mungo Park* found beer made of the grain called *holcus spicatus:* but whatever grain be employed, the process of making the beer is nearly the same. The barley is steeped in water for about 60 hours, in order to saturate it with the liquid: it is then removed as speedily as possible, otherwise the water will dissolve and carry off the most valuable part of the grain. The barley is then laid in a heap for 24 hours; heat is thrown out, oxygen gas, (vital air) is absorbed from the atmosphere, carbonic acid gas, (fixed air) is emitted, and germination (shooting of the radical downwards, and of the plumula upwards) commences. In this state the barley is spread upon a cool floor, slowly dried, and then becomes *malt.*

Malt, previously ground to a coarse powder, is infused in a sufficient quantity of water of the temperature of 160° for an hour. The infusion is then drawn off, and more water may be added, at a higher temperature, till all the soluble part of the malt be extracted. The infusion is called *wort:* it has a sweet taste, containing a quantity of sugar, and also some gelatinous matter. In some parts of this country it is usual to mix two parts of ground barley with one part of ground malt; an operation which is found to yield an equal quantity of beer, and of a quality rather superior to that of beer made from malt alone.

The wort is conveyed to a boiler where it is boiled with *hops* or some other equivalent bitter, and then put into large fermenting vats. The effect of the bitter is not only to render the sweetness of the wort more grateful to the palate and stomach, but to preserve it from rapid decomposition. For the bitter principle existing in many vegetables differs considerably from every other substance found in them, particularly in resisting the action of many powerful substances, by which the wort alone would soon be destroyed. The nitrate of silver, and the acetate of lead, (silver dissolved in aquafortis, and lead in vinegar) are the only bodies that will precipitate this bitter principle from the infusion of vegetables containing it.

When wort is placed in the temperature of 60°, fermentation gradually takes place in it and the very same things occur as in the production of wine. The fermentation of wort then is only a particular case of the vinous fermentation. But wort does not ferment so soon nor so well, nor does it produce so great a quantity of good liquor, as when barm or yeast is added to it. The reason of this is probably that fermentation does not commence till an acid be produced in the wort, and before that happen part of the saccharine contents are decomposed; whereas the yeast at once furnishes an acid, or at least something equivalent to an acid.

Wort ferments in close vessels equally well as in the open air: the decomposition therefore is entirely produced by the substances contained in the wort, and not by any thing drawn from the air. The quantity of beer produced in close vessels is besides much greater than when the process takes place in the open air; because in the air a great deal is carried off by evaporation, and that too of the finer parts. By experiment it was found that 11 quarts, fermented in open vessels, lost in 12 days 40 ounces; whereas an equal quantity fermented in close vessels, for the same time, lost only 8 ounces, or one-fifth of the loss of the other quantity. Yet the quality of the beer was the same in each as to strength, for equal quantities of both yielded by distillation the same quantity of spirit. When beer is distilled, alcohol or ardent spirit is obtained, leaving behind an acid liquor, the nature of which is still unknown.

A German physician who wrote on the medicinal properties of beer, in the beginning of the reign of our Queen Elizabeth, about 250 years ago, reports that in his time three kinds of beer were used in England, the one called *single*, and the other *double* beer, and the third of an intermediate strength between them called *three-halfpenny*. Besides these liquors was he says a third called *ale*, made entirely of malt without hops or any other bitter. This sort was used only by the more delicate classes of the English nation, and was very heady, and by no means so wholesome as the other kinds of beer.

4. *Of Vinegar.* If wine or beer be kept in a temperature between 70° and 90°, they become thick, their temperature augments, filaments or threads appear to move through the liquors in all directions, and a kind of hissing noise may be distinguished. These motions after some time disappear, the filaments attach themselves to the sides and bottom of the vessel, and the liquor becomes transparent. It has now however lost its former properties, and is converted into acetous acid or pure vinegar. The weaker the wine or the beer, the more readily are they turned into vinegar: but when strong wine or beer are made to undergo the acetous fermentation, they produce a vinegar much stronger and better than that made from weak wine or beer. If wine be entirely deprived of extractive matter, it does not turn to vinegar, unless some mucilaginous or gummy substance be mixed with it. Old wine that had deposited all its extract, or crust as we call it, was exposed in open bottles for 40 days together, to the hot summer sun of the south of France, and yet never became sour: but when some vine leaves (in which a little gum always exists) were put into the bottles, the wine became acid in a few days. Wine never becomes sour, provided it be completely deprived of all access of atmospheric air. The reason is, that, during the acetous fermentation, oxygen is absorbed from the air,

by which alone vinegar can be formed. Hence we find wine or beer to be more apt to become sour, after the cork has been drawn, or if even badly corked, and still more so when part of the liquor has been poured out, and the air admitted into the bottle in its place. Though vinegar be chiefly prepared from fluids which have undergone the vinous fermentation, yet this is not necessary to its production; for simple mucilage or a watery solution of gum will pass into the acetous fermentation. When the saccharine principle predominates in any substance, exposed to the necessary conditions of fermentation, alcohol or spirit of wine is the product: when mucilage is most abundant vinegar or acetous acid is produced: and when gluten, (a substance greatly resembling animal matter, found in certain vegetables, particularly in wheat-flour) is predominant, ammonia will be produced, and putrefaction or the putrid fermentation takes place.

5. *Of putrefaction of vegetables.* All vegetable substances when left to themselves are gradually decomposed and destroyed, provided moisture be present, and the temperature be not much under 45°, nor too high to evaporate suddenly all the moisture. This decomposition is called *putrefaction,* from the Latin term expressing corruption. This process takes place the most rapidly in the open air; but the contact of the air is not absolutely necessary: water however is in all cases essentially requisite.

Putrefaction of vegetables, (for of animal substances we here take no notice,) is constantly attended by a fetid odour, produced by certain gaseous matters, differing in quality according to the putrifying substances. When the whole process is finished scarcely any thing of the vegetable remains but the salts, the metals, and the earths, of which it was constituted.

6. *Of Gas Light.* It was formerly observed, that by *gas,* a term derived from the German, is understood certain elastic vapours procured by the action of fire or of fluids on various substances. The gas employed as the means of producing light, and to illuminate houses, manufactories, streets, and whole towns, is drawn from *pit-coal.* This substance exists in immense beds in this country, in the western, middle, and northern parts of England, and in the western, middle, and eastern parts of Scotland. It consists, like other bituminous substances, of a fixed carbonaceous base or bitumen, united to more or less earthy and saline matters, which compose the ashes remaining behind when the coal is burnt. The proportions of these component parts vary considerably, in different kinds of coal: and according to the prevalency of one or other of them, the coal is more or less combustible; passing gradually from the most inflammable of all, called in England *cannel* coal, and in Scotland *parrot* coal, down to *blind* or stone coal.

Pit-coal may be divided into several kinds; the 1st composed chiefly of asphaltum or bitumen, which take fire readily, and burn briskly with a brilliant strong blaze, but neither swell nor coalesce into coke in the fire; requiring no stirring, producing no slag, but burning to light white ashes. Most of the coals of Lancashire, and the west of England are of this kind, at the head of which stands cannel coal. This sort is occasionally found in the Newcastle pits; but the splint and most of the other Scotch coals are of this lively sort.

The 2d class of coals is composed of those which contain a smaller quantity of bitumen, and a greater of carbon than the first class; burn-

ing with less brightness, becoming soft and swelling when some time on the fire, after which they cohere and form coke, throwing out small jets of flame with a hissing noise. From this coherence the passage of air through the fire is interrupted, so that the top of the coal requires to be broken from time to time by the poker. Coals of this kind, of which the Wallsend are the chief, are excellently calculated for standing the blast of the furnace or forge. A mixture of two parts of this strong coal, and one part of the first kind forms the best fuel for all domestic purposes.

The 3d kind of pit-coal consists of those sorts which are almost destitute of bitumen, chiefly composed of carbon combined with much earthy matter. Coals of this kind require a temperature to set them on fire much higher than any of the former classes: they give little or no smoke or flame, and consume without caking, leaving but a small proportion of heavy ashes.

Of all these kinds of coal those of the first class, viz. the Lancashire cannel, and Scotch splint, are the best adapted for conversion into illuminating gas. They require less heat to turn them into carbon than the Newcastle coal, and the gas they yield is readily purified, producing also a very brilliant white light.

When *pit-coals* are burning in the grate, a flame, more or less bright, issues from them, and beautiful streams of remarkably luminous flame are often suddenly and violently thrown out. Besides these flames, consisting of a peculiar gas in a burning state, the heat expels from the coal a watery vapour loaded with several kinds of ammoniac salts, a thick viscid fluid resembling tar, and some kinds of gas not of a combustible nature. The consequence of all this is that the flame of a coal fire is continually wavering and changing in shape, colour, and brilliancy. But if coals, instead of being burnt in this way are submitted to distillation in close vessels, all these component parts may be separately collected. The bituminous part is melted out by the external heat in the form of tar; a large quantity of watery fluid is disengaged, but mixed with oil and different ammonic salts; a large quantity of carbureted hydrogen, (carbon combined with hydrogen one of the component parts of water,) and other uninflammable gases make their appearance; and the fixed base of the coal remains behind in the still in what is called coke. These several products may be all separately collected in different vessels. The carbureted hydrogen, or the *coal-gas*, may be separated from the uninflammable gases, and then made to pass in streams through small apertures, so that when set on fire it may serve in the place of candles or lamps to illuminate a room or other place Thus from our ordinary fuel, pit-coal, may be procured a light copious lasting and pure: and it is upon the power of collecting the several products of coal that the system of gas-lights is founded. The *flame* of coal in our common fires is turned to very little or rather to no advantage at present: it is not only confined to one single place, the chimney, where a steady red heat would be much more beneficial; but it is also smothered by a quantity of incombustile substances carried off from the coal with it, which notoriously load and pollute the atmosphere we breathe.

That much inflammable matter is thus lost, is evident from what we daily observe. Often do we see a flame suddenly break out from the thickest smoke, and as suddenly disappear: and if a light be applied

to the little jets of vapour issuing from the bituminous parts of the coal, they will catch fire and burn with a bright flame. A considerable quantity of gaseous fluid, capable of yielding light and heat, is always carried up the chimney, whilst another part is occasionally inflamed, and answers the purposes of the fire.

The production of gas-light, is similar to the action of a lamp or a candle. The wick of a candle surrounded by the flame is in the same situation with pit-coal exposed to distillation The office of the wick is to convey the tallow or wax, by attraction, to the place of combustion. Being decomposed into carbureted hydrogen gas, the tallow is consumed and flies off; another portion succeeds, and in this way a constant current of tallow, and maintenance of flame are produced. The combustion of oil in a lamp is brought about in the same way. The tubes formed by the substance of the wick serve the same office as a retort placed in a heated furnace, through which the inflammable liquid is transmitted. The oil is drawn up into these burning tubes, and converted into carbureted hydrogen gas; and from the burning of this gas proceeds the light of the lamp. The object therefore of the gas-light plan is, by the means of furnaces and reservoirs, to produce and preserve for use a quantity of the gas which furnishes the luminous flame of candles and lamps. This gas is then to be transmitted to the desired distance through pipes, at the extremity of which it may be set on fire, to give light for any specific purpose. The only differences between this process and that of the candle or the lamp are that, in the gas system, the furnace for producing it is at the manufactory, whereas in the candle or lamp it is in the wick,—that the inflammable material is prepared at the gas station, instead of appearing as tallow, wax or oil,—and that the material is conducted to any convenient distance, and there set on fire at the end of the conducting pipe, instead of being inflamed at the point of the wick.

Pit-coal contains hydrogen, carbon, and oxygen. When the heat is arrived at a certain point a part of the carbon unites with a part of the oxygen, and produces carbonic acid, which by caloric is brought into the gaseous state, forming carbonic acid gas. At the same time part of the hydrogen combines with another portion of carbon and caloric, forming carbureted hydrogen gas, which varies in its nature according to the circumstances under which it is produced. This last substance is not obtained from pit-coal only: it is found plentifully ready-made on the surface of stagnant waters, marshes, wet ditches, &c. from which air-bubbles may be observed to rise, in hot weather, and may be increased at pleasure, if the bottom or mud be stirred with a stick. In a close still evening, if a lighted candle be held near the surface of such places, flashes of blue dancing flame may be perceived spreading over it. To this is probably owing the *ignis fatuus* or *Will o'the wisp.*

To convey to the reader any competent idea of the machinery necessary for the preparation of illuminating gas, from coal or other substance, would require a number of plates, and an extent of description incompatible with the nature of the present work. He will therefore be contented to peruse the following short account of the apparatus at present employed in different parts of London.

The pit-coal to be distilled, as it may be called, is introduced into a long narrow iron vessel or retort, of a form nearly cylindrical, but some-

what wider at the mouth than at the bottom. This retort, when the operation is carried on in a small way, is sunk deep in the coal of a furnace; but when gas is required in sufficiency to light a large building, a manufactory, a street, &c. several retorts become necessary, which are laid on their sides over a furnace of which the heat is, by means of flues, made completely to play round them. The mouth of each retort is closely stopped up, so that none of the substances produced from the inclosed coal can possibly escape, excepting through tubes fitted to each for that purpose. When the inclosed coal is acted upon by the heat of the furnace, the liquid and gaseous substances driven from the coal are transmitted, by means of the tubes just mentioned, which rising perpendicularly are again bent down, into a large horizontal pipe or main conductor. The distilled liquid is collected in this conductor, until it accumulate to such a quantity as to flow out through a pipe inserted near the upper part of one of the ends. By this pipe the vaporous and condensible fluids are conveyed into the upper part of a cistern filled with pure water, down through which the pipe descends, in a winding form, like the worm of a common distilling apparatus. Cooled by passing through this body of water, the condensible parts are conveyed into a vessel, situated lower than the issue of the pipe from the cooling cistern, where they are collected in the form of tar; while the non-condensible or gaseous parts pass into another vessel, where they are brought into contact with slaked lime and water. Here the gas as it proceeds from the distilled coal is deprived of its sulphureted hydrogen, and carbonic acid gas, with which it always abounds, and is thereby rendered fit for inflammation and illumination. This being accomplished, the gas so far purified is carried away from the lime vessel, by a pipe communicating with another which rises perpendicularly in the middle of the bottom of the great water-cistern. The upper end of this pipe is covered by a cylindrical hood, open at the bottom and pierced with small holes in the sides, and partly immersed in the water of the cistern. Over the surface of the water is suspended a vessel made of sheet-iron, large enough to go just within the frame of the cistern. This vessel is closed above but open below, so that it will sink in the water, when the air within it is allowed to escape by apertures in the upper surface. It is suspended by a chain at each end, passing over pullies above, and nearly counterbalanced by weights, so that a small additional weight or upward pressure will raise it. This part of the apparatus is called the *gasometer*, because by its rising or falling it shows the quantity of gas contained in it. The purified gas rising through the perpendicular tube in the middle of the cistern, being greatly lighter than the water in the hood or cover, rises above it, and then escapes through the perforated sides into the great body of surrounding water in the cistern; up through which it again rises into the gasometer resting on the surface. Accumulating there, it gradually elevates the superincumbent gasometer, as long as the distillation of the coal continues to produce gas, which after thus passing through the lime and a body of water, becomes sufficiently purified for affording light. To the upper part of the gasometer are adapted pipes into which the gas there collected enters, and is forced along by the pressure of the frame, which is therefore a little heavier than the suspending weights. If now a light be applied to the open end of these pipes, the gas will immediately take fire, and burn with a brilliant

lively flame, as long as any remains in the gasometer, which will gradually sink down to the surface of the water in the cistern, if the whole gas be consumed and not replaced by more by continuing the distillation of the coal. The issue of the inflammable gas from the main pipes, or from any particular branch, is stopped or allowed at pleasure, by turning a cock near the extremity.

The inflammable gas produced from coal may be preserved in a reservoir, where it has no communication with atmospheric air, for any requisite time; and by opening a stop-cock at the end of a tube connected with the reservoir, and applying a lighted taper or piece of paper, it instantly bursts out into a brilliant, noiseless, steady, beautiful flame. Its purity, when properly managed, is shown by its never blackening or soiling the opening of the tube from which it flows. No combustible matter in the gas can escape unconsumed; consequently no soot or smoke can be produced. The products of the combustion are water and carbonic acid gas. The water passes off in imperceptible vapour; and by accurate experiments it has been proved that the carbonic acid is produced in far smaller quantities from the flame of coal gas than from that of oil, tallow, or wax. The gas flame is instantaneously extinguished by turning the stop-cock, which cuts off the supply from the reservoir.

Besides light a very considerable degree of heat is produced by the gas: this must be sensible to every person who chooses to make the trial; for the gas flame condenses much more air, and consequently extricates much more heat than the flame of oil or tallow. From this valuable property the gas may be exhibited on so large a surface as not only to illuminate but to warm the most spacious apartments.

The expence of gas illumination, after the first establishment of the apparatus, is trifling; and this first cost is soon reimbursed by the great saving in candles or oil, as well as by the value of the tar and coke produced in the manufactory of the gas.

CHAP. III.

AGRICULTURE.

Agriculture is the art of making the earth to produce, in the largest quantities, and in the greatest perfection of which their nature is susceptible, vegetables necessary for the subsistence, or useful for the accommodation of man. It differs from gardening in this respect, that the gardener is occupied in raising small quantities of the more nice and delicate vegetables, valued rather as articles of luxury than of necessary food, whilst the agriculturist works upon an enlarged plan, with the view of supplying his countrymen, and even other nations, as well as himself and his family, with the necessaries of life.

To enable the agriculturist, the cultivator, the husbandman, the

farmer, (for these different appellations all point out the same person and character) to carry on his business with just hopes of success, his attention must be directed to other objects besides the mere labour of the ground and the rearing of vegetables. Such plants as afford nourishment to the human frame are comparatively few in number; nor can they be profitably produced, year after year, from the same ground. Hence it is necessary occasionally to cultivate grasses and other vegetables, unfit for the use of man, but which may, in an indirect way, be rendered conducive to his sustenance. Those grasses and other vegetables are the natural food of cattle; and being thus in some measure converted into animal substances, they furnish the richest, and most nourishing, and strengthening food for the human race. Hence it becomes an essential part of the business of the husbandman to rear and feed those animals which serve for the sustenance of society. Besides these animals, however, others not immediately destined for food, demand his attention, on account of their assistance and utility in the cultivation of the soil.

From these, and other considerations that will readily occur to the reader, it will be evident that the business of the husbandman is neither confined in extent nor easy in nature, that it requires great foresight, and an intimate knowledge of many important objects around him, of the soil, the seasons, the animals, the plants, as far as they are connected with the support of human existence.

It is a fortunate circumstance that the art of husbandry, the foundation of all other arts, is in every respect conducive to the welfare of those engaged in it. The practice of it bestows health upon the body; and the variety of its occupations furnishes an abundant employment for the mind of the humblest persons concerned in it. It has also a beneficial effect, in a moral point of view, as it has no tendency to excite or encourage that spirit of cunning and artifice, which too frequently degrades the character of persons engaged in the inferior branches of commercial and manufacturing employment.

The art of the husbandman is unquestionably the most ancient of all. Scripture informs us that Adam was sent from the garden of Eden to labour or cultivate the ground, although we are not to imagine that he immediately understood and practised our methods of digging, plowing, harrowing, fallowing, and the like. From the earliest accounts of the nations of the East, agriculture seems to have been carried by them to considerable perfection. As soon as the descendants of Abraham were settled in Palestine, they became in general husbandmen, from the highest to the lowest. High birth and rank made in this no distinction; for agriculture was considered as the most honourable of all employments; of which the history of Gideon, of Saul, of David, furnishes illustrious examples. The Chaldeans who inhabited the country where agriculture had its birth, carried that art to a high pitch of improvement. The Egyptians who, from the fertility of their soil, enriched by the overflowings of the Nile, raised vast quantities of corn, for the use of other nations as well as for their own wants, so highly esteemed the art of the husbandman as to ascribe its origin to Osiris their principal divinity. It was the practice among the ancient Persians for the kings, once in every month, to lay aside their grandeur and eat with husbandmen. The precepts of their religion included the practice of agriculture. It was even a maxim in their sacred books, that he who sowed the ground

with care and diligence, acquired a greater degree of religious merit than he could have done by the repetition of ten thousand prayers. The ceremonious respect bestowed on agriculture in China is well known. There the husbandman enjoys many great privileges; while the trader and the mechanic are held in comparatively little estimation. In the beginning of the spring of every year, the emperor in person, attended by chief men of the state, repairs to a field prepared for the purpose, and there with his own hands holds the plough and turns up some furroughs; the princes and nobles do the same after him according to their rank; then the emperor sows the seeds of wheat, rice, millet and beans, and covers them over with the soil.

When agriculture was first introduced into Britain, cannot now be known: but it was practised in Kent and other maritime parts, when Cæsar invaded the island, nearly nineteen hundred years ago, and in his opinion it had been introduced by colonies from the opposite shores of the continent. The establishment of the Romans in this country produced many improvements in husbandry, so that prodigious quantities of corn were exported: but when the Roman power began to decline, this and other arts were almost totally overthrown. After the introduction of the Saxons into the southern parts of the island, in the year 449, the native Britons were driven into the mountainous districts where agriculture could scarcely be carried on. Laws were however made among them for its encouragement, and regulations for its practice, from which some notion may be formed of its miserable state. It was enacted, that no man should undertake to guide a plough who could not make one; and that the driver should make of twisted willows the ropes by which the plough was drawn. It was customary for six or eight persons to form themselves into a society for fitting out a plough, providing it with oxen and all other necessaries. If any person laid manure on a field, with the consent of the proprietor, he was entitled to the use of the land for one year. If the manure was carried out in a cart, in great abundance, he was to enjoy the use of the land for three years together. Whoever cut down a wood, and brought the ground into arable land, all with the consent of the owner, was to have the use of the cleared land for five years. If any one folded his cattle, for one year, upon a piece of ground belonging to another person, and by his consent, he had the use of the field for four years. The Saxon princes and great men who, in the division of the lands of the Britons, received the largest shares, distributed their possessions into two portions, *in-lands* and *out-lands*. The in-lands were those round about the owner's place of residence, and cultivated by his own slaves for his own use. The out-lands were those at a distance from his residence, let to the *ceorls* or farmers of those days, at very low rents. By a law made in the beginning of the eighth century, a farm consisting of ten *hides* of land was to pay the following curious rent, viz. ten casks of honey, three hundred loaves of bread, twelve casks of strong ale, thirty casks of small ale, two oxen, ten wedders, ten geese, twenty hens, ten cheeses, one cask of butter, five salmon, twenty pounds of forage, and one hundred eels. The *hide* of land or plough-gate was as much as could be laboured with one plough in a year, or as much as would maintain a family, and computed by some to signify sixty-eight, or one hundred acres. The value or price of land when sold, even of the best quality, was at the same period, no more than sixteen Saxon pennies, equal

to about four shillings of our present money per acre; a very inadequate price when compared with that of other commodities at the same time, when four sheep were equal in value to the price of an acre of the best land, and one horse equal in value to three acres.

The invasion by William the Conqueror, in 1066, contributed greatly to the improvement of agriculture in England, by the settlement of many thousands of husbandmen, from the fertile and well cultivated districts of France and Flanders. It was however as late as the beginning of the sixteenth century before agriculture came to be studied in a regular scientific way, either in England, or on the adjoining regions of the continent: but in our own times every encouragement from governments, as well as from public bodies and individuals, has been held forth, to engage ingenious cultivators to pursue courses of practical experiment and improvement of an art on which the welfare of society so greatly depends. Among these attempts it will be sufficient to mention the establishment of the *Board of Agriculture.* About the year 1790, *Sir John Sinclair of Ulbster,* in the north of Scotland, baronet, invited the clergy of Scotland to furnish him with descriptions of their several parishes, with a view to the publication of a statistical account of that kingdom. This request being readily complied with, a work in twenty volumes octavo, was drawn up from the materials afforded, the only work of the kind possessed by any country, containing with various other useful and important matters, historical, biographical, and antiquarian, accurate accounts of the agriculture, manufactures, and population of Scotland. Sir John Sinclair, was at the same time actively engaged in forming a private association, called *the British Wool Society.* Meeting with no small success in these patriotic endeavours, he was encouraged to make a motion in the house of Commons, of which he was a member, on the 15th of May 1793, recommending the establishment of a public board of agriculture. The measure being acceptable to the great majority of the house, Mr. Pitt, then chancellor of the exchequer, gave it his decided support: and without loss of time a charter was granted for the institution, at an expence out of the public purse, not to exceed L. 3000 annually. Of this board the ministers of the crown, with the archbishops of Canterbury and York, and their successors in office, are always to be members. The other members appointed were noblemen and gentlemen, who had distinguished themselves for zeal and intelligence in the improvement of husbandry. The first president was the original projector Sir John Sinclair, and the institution was intitled *the Board or Society for the Encouragement of Agriculture and internal Improvement.* The regular meeting, of the board for ordinary business did not commence till the 23d of January 1794; since which time it has exerted very considerable activity and influence in establishing correspondence, even with foreign countries, and in procuring and publishing every kind of useful domestic agricultural information. One of the first objects of the board was to employ persons of established skill and character, to prepare agricultural surveys of every county in the island of Great Britain, of which many have already been published, forming treatises upon the important art of husbandry, in all its branches, which for extent of information and ability of execution, stand unequalled by similar productions of any age or country. The board has also obtained rewards from parliament to persons who have made important discoveries, and offered premiums for

papers upon subjects connected with the business of the institution, which have produced a great variety of very ingenious and valuable disquisitions.

Theory or principles of agriculture. A general view of the principles of agriculture is naturally divided into two branches: 1st, to enquire among the vast variety of vegetable productions, what are the particular kinds that deserve most particularly to be cultivated, and 2dly, to consider the best mode of cultivating with success the kinds thus selected.

1st. Of annual plants cultivated for the food of man, *wheat* has always been accounted the most valuable; owing probably to the ease with which it can be fermented, and so rendered a lighter and more agreeable kind of bread than that made from any other grain. This property arises, it is believed, from a quantity of a substance contained in wheat, of the same nature with the *gluten* or glue prepared from animal substances. In other respects however it does not appear that wheat is more valuable than some other sorts of grain; for by means of long boiling a given quantity of barley, or even of oats, the water will become as thick and full of mucilage or gluey matter, as it would have been by a similar process with an equal quantity of wheat.

After wheat *oats* have in many countries been considered as of the greatest importance for bread-corn, and other human food. The plant is hardy, grows with little cultivation, and is particularly well suited for lands newly brought out of a state of nature, upon which it was always used as the first crop, until the introduction of the turnip husbandry. The meal of oats is usually ground very coarse or in large grains, and is mixed with a quantity of the inner covering of the seed. Hence the meal has a considerable degree of roughness which renders it unsuited to very delicate constitutions: but this very harshness acting on the stomach, produces a feeling of warmth, which renders it acceptable to persons much exposed to the open air in all seasons, and accustomed to hard labour, who consider it to be a hearty kind of food. Some of the healthiest, the most robust and active men, not of this kingdom only, but of countries situated in corresponding climates on the continent, subsist chiefly on oat-meal prepared in various ways, alone, or mixed with rye, barley, &c. reduced to flour.

Barley is chiefly valued for the facility with which it produces a vast quantity of saccharine or sugary matter, by the process of artificial vegetation which we call *malting*, by which the grain is prepared for making vinous or spirituous liquors. *Pease* are also sometimes used when ground into meal, as human food: but on account of their viscid or tough, and consequently indigestible quality, they can never become valuable in that view, unless to persons of strong habits of body, engaged in the open air in labour of the most severe and active kind.

In general it may be observed, that, in point of quality and wholesomeness, there is not much difference between the various kinds of grain cultivated in different countries. They are all capable of nourishing the human frame, and of preserving it in health and vigour.

Of roots commonly used for the food of man the *potatoe* has hitherto been the principal. Others, as carrots, turnips, parsnips, are never used as the only food, being rather adapted to give variety and relish to other viands, particularly animal food. The potatoe is, however, in some respects, an exception; for it contains a large quantity of starch, not perhaps inferior to the starch of wheat, in as far as that substance

is necessary for nourishment. That potatoes are capable of nourishing a strong and healthy race of people is evident from the great body of the natives of Ireland, who have, for a great length of time, subsisted almost entirely upon that admirable root.

It is worthy of remark, that a crop of all the above mentioned roots will always produce a much greater quantity of human food than a crop of any kind of grain whatever, upon an equal extent of ground. By experiments made in Scotland, it was found that an acre of good land, which would not produce more than 1280 pounds weight of oatmeal, would, in favourable seasons, yield from thirty to thirty-five thousand pounds weight of potatoes; and even in unfavourable years above twenty thousand pounds. Now supposing one pound of oatmeal to contain as much nourishment as four pounds of potatoes, still the quantity of food produced by the potatoes must greatly exceed the quantity arising from the same extent of equal ground cultivated with oats. A similar result will be drawn from a comparison of potatoes with wheat or any other grain.

Potatoes, however, and all the other roots have hitherto been attended with several great defects. In consequence of their bulk and weight, from their extreme moisture, their carriage becomes very inconvenient and expensive. Roots are also incapable of preservation; in winter they are destroyed by frost; in summer by heat, both which contrary causes equally render them unfit for human food. Roots are also much more bulky than grain, in proportion to the quantity of nourishment they contain: hence they are less fit for persons engaged in sedentary occupations, who generally find them inconvenient and even hurtful to the stomach by their bulkiness, and their tendency to counteract digestion, producing flatulencies and other disagreeable consequences. On the whole, the difference between juicy roots and the grain of corn plants seems to be chiefly this, that, although both are formed of similar substances, the potatoe being related to wheat, the carrot and parsnip to rye, or rather to barley when converted into malt, yet as the roots are formed in the bosom of the soil, and are of a loose and watery texture, their formation requires from nature less effort than the production of small grains growing in the open dry air, at the top of a plant. Thus nature by an abundant crop of roots makes up for the inferior quality of her productions. To remedy this defect in roots many ingenious methods have been contrived and practised, in order to deprive them of their superfluous moisture, to bring them as near as possible to the value of grain in point of quality, while in quantity they are so much superior: but of those methods it would be impossible to give any proper notion, without going into greater length, and exhibiting more plates than can suit the nature of this work.

2d, Of vegetables for food of cattle. In this inquiry which has been much less attended to than it deserves, sundry points are to be considered; namely the wholesomeness of the food with regard to its effects on the health, the strength, or the fattening of the animals;—the quantity of food that can be raised on any given extent of land;—the quantity of food necessary for the different kinds of cattle;—the labour and expence of cultivation;—and the kind of soil required to bring the different sorts of food to perfection, and the effects they have upon the soil.

With regard to wholesomeness, as the natural food of cattle in a wild

state must be the green succulent or juicy plants they find all the year round, food of this kind must be preferable to hay or dried herbage: and we accordingly find that even animals in a tame domestic state will always prefer succulent plants to dry food, when they have opportunities to do so. To find plants of this sort we must look for those which continue green all the year round, or which come to perfection in winter. Of these plants cabbages seem to hold the first rank, as being very juicy, and growing in large quantities on a small piece of ground. On an average of the quantity of cabbages, produced on an acre of ground, recorded in Mr. Arthur Young's agricultural tour in England, it appeared to be 36 tons. Cabbages however have this inconveniency that they sometimes communicate a disagreeable flavour to the milk, and even to the flesh of animals fed on them. This however may be, in a great degree, prevented by carefully picking off the decayed leaves; for no vegetable inclines more to putrefaction than cabbage: and for milk-cows they might probably be rendered fitter food by boiling them.

The turnip-rooted cabbage, and turnips, are of late much cultivated: and both seem to be most important articles in farming. According to Mr. Young, the finest soil does not produce above five tons of turnips per acre; a very great inferiority in quantity to cabbages; but possibly much less turnip would be consumed by cattle in general than of cabbage. An ox weighing 80 stone was observed to eat 210 pounds of cabbages in 24 hours, besides 7 pounds of hay. Carrots are also excellent for all cattle, and much relished by them. In rich sand an acre has yielded 200 bushels: but in a finer soil the produce was 640 bushels per acre. A lean hog was fattened by carrots in ten days time, during which he ate 196 pounds; and his fat was very fine, white, firm, and did not boil away in dressing. Carrots are preferred by cattle to turnips; and they are probably much more wholesome food than either turnips or cabbages; the virtues of a carrot-poultice in cleaning and healing ulcers on the human body, are strikingly efficacious. It is probably on this account that the milk of cows fed upon carrots never has any bad taste. Six horses kept on carrots throughout a whole winter, without once touching corn, performed their work, and looked as well as usual. In Yorkshire, 20 work horses, 4 bullocks, and 6 milk-cows were fed on the carrots raised upon 3 acres of ground, from the end of September, to the beginning of May; the animals never tasting any other food but a little hay. The milk of the cows was excellent, and 30 hogs were fed upon what was left by the cattle.

Potatoes are also very palatable food for cattle of all kinds; not only oxen, hogs, &c. are easily fed upon them, but even poultry. The cheapness of potatoes compared with other kinds of food for cattle cannot be properly estimated; for besides the advantage of the crop, the culture of potatoes is of vast service in improving the ground, by breaking down the soil and clearing it of weeds. A correspondent of the Bath Agricultural Society, states, that roasting pork was never so moist and delicate as when fed from potatoes, and killed from the barn door without previous confinement. For bacon-hams, he says, 2 bushels of pea-meal should be well mingled with 4 bushels of boiled potatoes, which quantity will fatten a hog of 12 stone of 14 pounds to the stone. Cows are particularly fond of potatoes: half a bushel at night, and as much in the morning, with a small quantity of hay, are sufficient to

keep 3 cows in full milk, yielding as much and as sweet butter as the best grass. A beast of 35 stone will require a bushel per day; but will fatten one-third sooner than on turnips. The potatoes should be well washed, and not given until quite dry again. It is not necessary to boil them, unless for bacon hogs, and poultry. The champion potatoe answers best of all. For horses and colts the effects of potatoes are not so well ascertained, although in many cases they have been employed with great success in the room of oats.

Other vegetables employed with advantage for green winter food are *buck-wheat, whins* or *goss,* cut down and bruised in a proper mill, and *burnet;* but on this last, opinions are divided. The *white beet* and *mangel wurzel* or root of scarcity have also been strongly recommended, as well as *vetches, lucern, tares, sainfoin, &c.* but in general it may be observed that the whole art of feeding cattle, either for work or for the table, is still as a science but in its infancy; the results of similar experiments, in apparently similar circumstances, being frequently very different from each other.

One important question has long been agitated among agriculturists, namely respecting the comparative profits to be derived from the cultivation of different vegetables. The husbandman, like every other artist or tradesman, must always consider himself as the servant of the public at large, and must endeavour to raise the vegetables that are chiefly in request, and that will enable him to obtain the greatest profit from his land. In forming his plan of husbandry therefore he must be governed by these two considerations. According to an average of many parts of England, for three years, one of them a fallow year, the *weight* of vegetable food from an acre of arable land was nine times and a half greater than that from an acre employed in feeding stock. According to calculations carefully made in Scotland, an acre of land in pasture fed with sheep produced 120 pounds weight of meat, whereas the same extent of similar land employed even in oats gave 1280 pounds weight of grain, or nearly eleven times the weight of the meat.

It seems impossible consequently for any nation to arrive at a very extensive degree of population, unless the people at large consent to live chiefly or altogether upon vegetable food. In China, where the practice of the rich and great in having a number of wives, renders their families very numerous, and where the equal distribution of the father's property among the children prevents the accumulation of great wealth by any individual, almost all persons have found it necessary, or at least convenient, to relinquish the common use of butcher's meat, and to subsist on vegetable food. And it is only in consequence of this practice that the prodigious population of China is maintained. The quantity of butcher's meat consumed in a country therefore will always set bounds to its population. Nations of hunters, and fishers, and shepherds, who live upon animals, wild or domestic, are without a single exception always few in number. By agriculture the numbers of animals fit for human food may be increased: but the men and families who can find employment in rearing them, or food by consuming them, must always be but one-fifth, or one-sixth part of those who might live upon the same territory, were the cattle removed, and the lands occupied in raising vegetable food for the immediate service of man.

Britain formerly produced abundance of grain, not only for its own

consumption, but also for exportation to other countries. When possessions beyond sea were established this surplus produce gradually fell off; and it appears from correct statements laid before parliament that, for a number of years back, notwithstanding all our great improvements in husbandry, and the quantities of common and waste lands brought into cultivation, the quantity of grain produced is gradually less and less equal to the consumption of the country. We are consequently under the necessity of purchasing more and more largely of grain from other states of Europe and North America, by which means the agriculture of those countries is greatly encouraged and extended. Even the infant settlements in the vast regions of New Holland, in the great Southern Ocean, have lately proposed to government at home to remit part of their superabundance of grain and other articles, for the supply of the mother country. Still however it is impossible not earnestly to desire that, in as far as agriculture and its consequent advantages to the support of population are concerned, we could be restored to our ancient independence on foreign countries for *the staff of life.* Such a state of independence is always advantageous, and often absolutely necessary for a community: and by agriculture alone, well understood and duly encouraged, can such an independence be secured.

> " Ye generous Britons venerate the *plough,*
> " And o'er your hills and long withdrawing vales
> " Let autumn spread her treasures to the sun:
> " So with superior boon may your rich soil
> " Exuberant nature's better blessings pour
> " O'er every land, the naked nations clothe,
> " And be th' exhaustless granary of the world."
>
> *Thomson's Seasons.*

Principles of cultivation. A vegetable is not to be regarded merely as a piece of matter, or only as a mixture of certain material substances. It is on the contrary a being endowed with organs necessary for the maintenance of its life, which is derived from another organised being of the same sort. A vegetable has not only birth from a parent vegetable, but growth supported and promoted by food, received and conveyed through its frame by organs adapted to its nature and wants. When come to maturity in form and constitution, it is able to continue its species, and then like an animal it decays and finally dies, after which by the process of putrefaction it returns to the earth from which it sprung. To the life of vegetables, as to that of animals, the air of the atmosphere is necessary, as also a certain degree of heat and moisture. They require also to be inserted in the soil, or in some way connected with it; for although we see some plants, particularly bulbous roots, such as onions, jonquils, &c. vegetating in pure water and air, without communicating with the ground, yet it appears that they gain but little addition to their substance, and that neither they nor any of the larger plants ever come to perfection, or produce seed, unless when planted in the soil or in communication with it.

As all soils are by no means equally fit for supporting vegetables, it is necessary for the husbandman to study their nature, and the means by which they may be altered and improved, until they be proper for his purposes. Besides the hard bodies called stones or rocks, the looser

and more divisible earth, composing the surface of our globe, and called in general *soil*, may be arranged under four heads, commonly intermixed with one another, and receiving their name from the substance in greatest quantity. These four substances are *sand, clay, chalk*, and *garden mold*. Of these sand and clay are, in some measure, the opposites of each other, while chalk forms a sort of medium between them. Sand allows water to filter freely through it, and speedily becomes dry, while clay is extremely tenacious of moisture; but a mixture of chalk renders sand considerably more capable of holding water, while it renders clay more loose and penetrable by water. None of these simple soils are valuable in husbandry: sand does not sufficiently retain water for the use of vegetables, and clay does not allow them freely to expand and send out their roots and fibres in search of nourishment. Chalk, or as it is commonly called a calcareous soil, is not by itself proper for raising useful plants: for though it may not have the mechanical defects of sand or clay, yet it is found to be of little service to plants, either from its tendency to destroy their substance by its corrosive and burning quality, as having too strong a chemical affinity with the materials of which plants consist, or from its not containing any materials proper for their food. The fourth kind of soil is called garden-mold, because it is in its highest perfection when it approaches the nearest to the rich black earth known by that name. This mold is the fittest of all kinds of soil for rearing the whole of the valuable vegetables of our climate; and in proper circumstances, with a due quantity of heat and moisture, it never fails to send forth and to bring to perfection an abundant crop. In proportion to the quantity of this black mold in any soil, its utility and value are increased. Loam is a mixture of sand and clay. It is proper to warn the husbandman that if he were able to cover all his possessions with a good depth of the best garden mold, its productiveness would not be constant. If crops of grain were taken from it, year after year, it would by degrees lose its fertile qualities and become unfit for agriculture. And in this lies the great difference between this compound soil, and the three simple soils, sand, clay, and chalk. Whatever properties these last possess are constant, and never perish: they can be changed only by the application of violent heat. But as it is only by the intermixture of these simple substances that vegetable soil can be produced, it is a matter of the most important concern to the cultivator to know the proportions in which they are to be mingled, and the means of restoring fertility to the compound mold when impoverished by use.

"Were a naked rock," says a correspondent of the Board of Agriculture, "suddenly thrown up from the sea or the bowels of the earth, the first plants which nature would place on it would be the various species of *lichens* or liverwort, and such as can subsist wholly on what they can imbibe from the air, without needing a soil in which to push out their roots. These plants serve the double purpose of clothing the rock, and thus preventing the fine particles dissolved by air and moisture, from being washed away; and from their growth and dissolution they accumulate vegetable soil for the sustenance of more succulent plants. The rock is thus gradually made to acquire such a depth of soil as to fit it for sustaining not only grasses and shrubs, but even the majestic oak itself." The progress of nature in clothing the barren rock with vegetation is correctly stated: but for the husbandman something

more must be added. Animal substances, when they have ceased to form parts of a living body, have a tendency to proceed rapidly to a state of putrid fermentation, by which the greatest part of their substance is rendered volatile and flies off in the air. When mixed with vegetable substances the animal parts quickly communicate their own fermentation or putrefaction to the vegetables, which then are decomposed, fall to pieces, and are converted into that kind of black earth called *garden mold,* which is the most fertile of all soils for the production of vegetables. It is by this process, that is by the fermentation of vegetable by means of animal substances, that the surface of our globe has been fertilised, by a rich black soil produced upon it, as we can daily see taking place in various situations. No sooner do the minute lichens or mosses cover the surface of the naked rock, or gravel, or clay, than a variety of small animals appear and feed upon them. As the plants and animals die in succession, their substances mingle and occasion the putrefaction before mentioned, which produces a small portion of soil. Upon the ruins of the former vegetables arises a new race of plants, of greater strength and bulk, supporting larger animals than the first; all destined in their turn to perish and to increase the quantity of the soil. More valuable grasses soon supplant the original diminutive vegetation, and the spot puts on a face of verdure. New kinds of animals begin to inhabit it: snails, worms, and insects abound, and by their dead remains contribute to the dissolution of the roots of plants which every where enter into the new soil, and to the decomposition of the stems which from time to time fall to the ground. When the soil has acquired a greater depth it is covered and sheltered by shrubs, and at last by forest trees, under the shade of which the largest animals can live and prosper. The trees shed their leaves every season, and every season will of course contribute an additional stratum, or layer, or coat of fertile mold to the soil: then while the forest endures, the fertility of the ground on which it stands will be continually augmented by its decay and spoils, and by the bodies of the animals resorting to it for shelter.

This process by which nature gives fertility to the earth, ought to be imitated by the husbandman; and it has in all ages been imitated, rather from experience and observation of facts than from speculations of science. In what way however, or by what peculiar operations, this kind of mold composed of fermented and putrefied animal and vegetable substances, becomes so highly conducive and subservient to the growth of plants, are points of no common difficulty in their solution: but fortunately such inquiries are comparatively of little importance to the practical agriculturist. He knows that by repeating the application of fresh vegetable and animal substances, in a state of fermentation, or beginning putrefaction, he can restore the powers of production to the exhausted soil, and that by no other process can its wonted fertility be recovered and rendered effectual.

Among the methods employed for the improvement of land, one perhaps the most useful is its pulverization, or separating as much as possible the minute particles of the soil from one another. This is chiefly done by repeated ploughings, especially when done in autumn, that the ground may be exposed to the action of the winter's frost. This must however be understood within certain bounds; for it would appear from experience that many *light* and *thin* soils receive hurt and not

advantage from frequent ploughings, especially when applied in summer, when the sun draws off the nutritive particles in great abundance, and thereby impoverishes the soil. The ground may also be broken and separated into small parts, by planting such vegetables of which the roots swell to a considerable bulk. The ground is acted upon in all directions by the swelling and pushing of the roots; so that the effects of the growing crop may fully equal those of repeated ploughings, with this great advantage that the crop itself may yield great profit, whereas from often ploughing alone, no profit whatever can immediately arise. The plant most remarkable for the swelling of its root is the potatoe; and by none is the ground so much bettered: but potatoes are not proper for all sorts of soil In clay, which stands the most in need of the separation of its particles, they neither thrive nor are good for food; but in hard gravelly or sandy soils they grow to a large size, and are of an excellent quality. Turnips also meliorate the ground by the swelling of their roots; but lying near and sometimes upon the surface, they are less useful than potatoes, although they thrive in any sort of soil. It has been practised in many places of England to sow turnip, pease, buck-wheat, &c. and when grown up, to plough them down as manure for the land. This being similar to the process of nature, in fertilizing uncultivated soils, cannot fail to be of great service; and might be reckoned preferable to the driving of manure to the field, were it not attended with this great disadvantage that by so doing a whole year and the crop are both sacrificed.

Practice of Agriculture.

This part of the art of husbandry naturally divides itself into four branches, 1st, of the most useful instruments employed in the labour of land, and in the preparation of its various productions: 2d, of the mode of preparing land for cropping, by removing obstacles to cultivation, and bringing the soil into a proper state: 3d, of the culture of particular plants, and the practices connected therewith: and 4th, of the principles and operations of the new or drill and horse-hoeing husbandry.

1st. Of the implements of husbandry. Of these there are a great variety; but the most common implements are *ploughs* of various descriptions, adapted to particular soils and situations of land, as well as to the animals employed in working them. The *Sward-cutter* originally intended to prepare old grass ground for the plough, by cutting it across the ridges in winter when the ground is soft: it is also very useful in fitting ground for burning-bating, and in cross-cutting clover of one or two years' standing, as a preparation for wheat, when the land is stiff and moist enough. In preparing for barley the sward-cutter excels a roller of any kind, in reducing the large hard clods in clay land, commonly formed by sudden drought after it has been ploughed in wet weather. One of these machines will cut as much ground in one day, as 6 ploughs can work in the same time.—The *cultivator* is an instrument intended to pulverize stiff soils that have been once ploughed, in a manner more complete and expeditious than can be done by any other instrument.—The *brake* is a large and weighty harrow for reducing strong and stubborn lands, where a common harrow makes little impression.—The ordinary *harrows* of different forms and uses.—The *roller*, of capital use in husbandry; but in general so light and slight as to

have very little effect.—The *fallow-cleaner* for the purpose of grubbing up chicks and other hurtful weeds from fallow grounds.—The *sowing machines,* when made of a simple construction, and consequently easily managed, and not liable to be put out of order, are of signal service in sowing seeds with great equality.

2d. The next head relates to the preparation of land for crop, by removing obstructions and bringing the soil into a proper state. *The removal of stones* is an operation of the utmost importance, for by them more expence is incurred in a season, by the injuries done to ploughs harness and cattle, besides loss of time, than would have been sufficient to remove the obstructions. The stones which interrupt improvements in land are either loose or thrown up by the plough, or such as seem to sit fast in the ground, and are too large to be moved by ploughing. The first sort may be gathered by the hand, and carried off the field; for they ought never to be laid down in heaps, but removed to places where they may be accessible for future purposes; if not in walls, yet in fences and drains, of which they are the most essential parts. Large or sitfast stones sometimes appear above the surface, and at others are entirely covered by the soil. Previous to breaking up waste land or common, in districts where large unwieldy stones are suspected to be concealed, it will be useful to go over the whole ground, thrusting into it a sharp iron prong, at least a foot deep, at the distance of every 15 or 18 inches, marking the spot where the iron runs against a stone, which is to be removed before the plough touch the land. One method of getting large stones on the surface out of the way of the plough is to dig a hole by the side of the stone, large enough to hold it and 18 or 20 inches deeper than its lower side. By a number of men the stone may be pushed over into the pit, where it will lie entirely below the touch of the plough. By this method, however, the stones, which might otherwise be of great value, are quite lost. For removing large blocks of stone, a machine is used in some parts of Scotland, which works upon the principles of the pulley and cylinder, or of the wheel and axis, having a power as one to twenty-four. The machine is extremely simple, being the common triangle or rather tripod of three poles meeting at the top, used for raising or weighing large and heavy bodies, to two sides of which the cylinder is applied; and a low four-wheeled carriage is brought under the arms of the triangle, to receive the stone when raised up: three men can work the machine, and remove it from place to place. When a field is over-run with concealed stones, however, the most effectual way to get rid of them, and to render the field perfectly arable, is to trench it entirely over with the spade. Nor is this way the most expensive, because by trenching the ploughing is saved, and the soil is deepened to the utmost extent which can be required, finely broken down and pulverised, and laid out in the best form for cultivation.

Draining. Moisture is of the utmost importance to the success of vegetation: at the same time, as must be the case with every powerful and active agent, the too great abundance of water is no less pernicious to many plants than the total want of it. When it stagnates upon the soil, water decomposes or rots the roots and stems of the most valuable vegetables: even when it does not remain the whole year round, its temporary stagnation during winter renders the land unproductive. For these reasons draining is of high importance, in order

to render the land manageable, and to dry it gradually and early in the spring, by which the corn will be increased in quantity and weight, and by which in pasture grounds the grasses change their dull colour and coarse appearance, and the finer kinds of plants are enabled to flourish. Even the climate is very sensibly improved by draining the land: for in winter it is less cold, and in summer vapours and exhalations are diminished, so that its wholesomeness to both animal and vegetable life is greatly increased. All kinds of grain come sooner to maturity; harvest is less precarious; and diseases produced by a damp soil and a moist atmosphere disappear.

The methods of draining land must be adapted to the causes of excessive moisture, according as it arises from stagnating rain-water, or from springs, or reservoirs in the bowels of the earth. To remove stagnating rain-water two sorts of drains are used, the open and the hollow drains. *Open drains* are exposed to view in their whole length; but *hollow drains* are entirely covered, so as to be imperceptible, and no land is lost upon their surface. Hollow drains are nevertheless often avoided, on account of the great expence of their construction; besides that in certain situations they would answer no good purpose. Clay soils cannot be drained by hollow channels; because such is the tenacity of the particles of clay, that water never filters or penetrates through it so far as to reach the drain: in soils therefore of this nature open drains alone should be employed. Soils consisting of tough tenacious clay are best drained by laying them up in ridges high in the middle, with furrows on each side, to receive and carry off the water; and the ridges and furrows should be so directed and managed that all the superfluous moisture should find its natural way to a common ditch or drain prepared to receive it. In Flanders, and in those parts of England where clay prevails, the usual way is to plough up the land in high broad ridges, 20, 30, and even 40 feet broad, having the middle or crown 3 or 4 feet higher than the furrows on each side. By this practice, and keeping the side-furrows free from standing water, the land is kept dry, and crops of all sorts flourish. In some rich strong clay soils in Scotland, common drains are carried through the district in various directions, to receive and carry off the water to the nearest river. Other ditches surround every farm, or pass through them, as may be necessary; but still communicating with every field of the farm. These ditches are from 2 to 4 feet wide at top, and from $1\frac{1}{2}$ to 1 foot at bottom: a shape which prevents the sides from sliding down. As it seldom happens, even in clay levels, that any field is so perfectly even and flat as to be free from every inequality of surface, the last work, after the land is sown and harrowed in, is to draw a furrow with the plough, through every hollow, making a communication with the nearest ditches. When this track is once opened with the plough, it is widened, cleared out, and so shaped with the spade as to run no risk of filling up. The width is from 6 to 12 inches, according to the depth: but the breadth of the common spade at bottom is generally sufficient. In plantations open drains only can be used: because the roots of the trees would be apt to choke up close or hollow drains. In pastures, small narrow cuts made with the plough or otherwise, are extremely useful: if they be easily stopt by the feet of the cattle, on the other hand they are as easily restored.

Hollow drains in which the water flows among loose stones or other

materials, through which it can easily pass, while they are covered with a bed of earth in which the plough can be carried on, bear a near resemblance to the natural mode by which water flows through layers of porous substances, in the bowels of the earth, and coming to the surface at different points, furnishes springs and the constant stream of rivulets and rivers. The practice of hollow draining is very ancient. In many parts of the interior of Asia, particularly in Persia, the inhabitants are supplied with water in their fields, by means of hollow drains, of the construction of which they are alike ignorant of the age and of the method. The oldest Roman writers on country affairs make mention of hollow drains, describing the manner of placing, digging, and filling them, very much in the way used in the present day.

When a field to be dried lies much on a slope, great care should be taken to make the hollow drains in a direction so nearly horizontal or level as to prevent a too rapid fall of the water, which would in time wear the bottom, and have the effect to choak or, as it is usually called, to *blow up* the drain, and so occasion springs of water to break out in the field. With respect to the season for draining no precise rules can be laid down, so much depending on the nature of the ground, the general state of the weather, the plenty and cheapness of labourers to do the work, and other circumstances on which the experienced farmer is best able to decide.

The depth and width usually adopted for hollow drains are very various. When the practice first came into use three feet were commonly allowed for the depth: but for many years past the depth seldom exceeds 30 or 32 inches; indeed more drains are made only 24 or 26 inches deep than of any other dimensions. One general rule however must never be overlooked, which is to sink the bottom of the drain so far below the surface, that the materials covering it, or filling it up, may run no risk of being injured or deranged by the feet of horses or cattle walking in a furrow while ploughing. For this purpose a depth of 2 feet is probably too little: a horse's foot in a furrow usually sinks four inches at least: if ten inches be allowed for the thickness of the materials in the drain, there will remain only ten inches of ground to support the foot of a horse exerting all his strength in the act of ploughing, which upon soft loose soil seems hardly sufficient. Where flat stones can be had, or when it is worth the charge to employ flat broad bricks or tiles, one method is to lay a tile or stone as the bottom of the drain, and two others upon it, meeting together at top so as to form a triangle. At other times the stones are reversed, two of them meeting together in the bottom, and their upper edges covered by a third, still forming a triangle, but the base uppermost.

The materials used for filling drains are various: stones however of a certain size are the most common, and likewise the most durable of all. When stones from the quarry are employed in a drain formed like a conduit, the trench should, at the bottom, be 16 inches wide, to contain two side stones about six inches asunder, and the same in height, with a cap or flat stone laid over to secure the cavity. Such hollow drains are necessary for constant runs of water from springs; only they are the most expensive. But in common drains, where loose stones whether large or small are thrown in promiscuously, the stones ought to be perfectly free from clay or earth, and of the hardest quality that can be procured; that they may have as little tendency as possible to

Plate 1

Fig. 1.

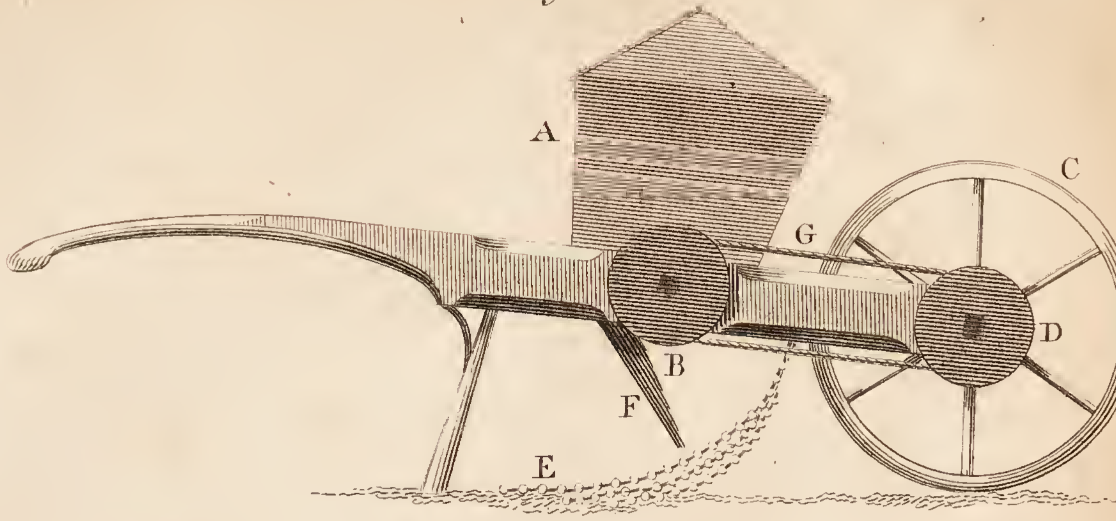


Fig. 2.

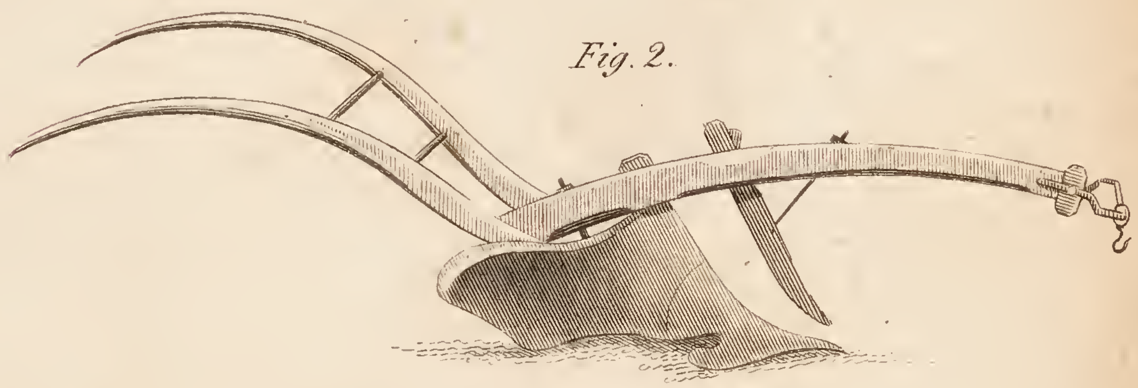
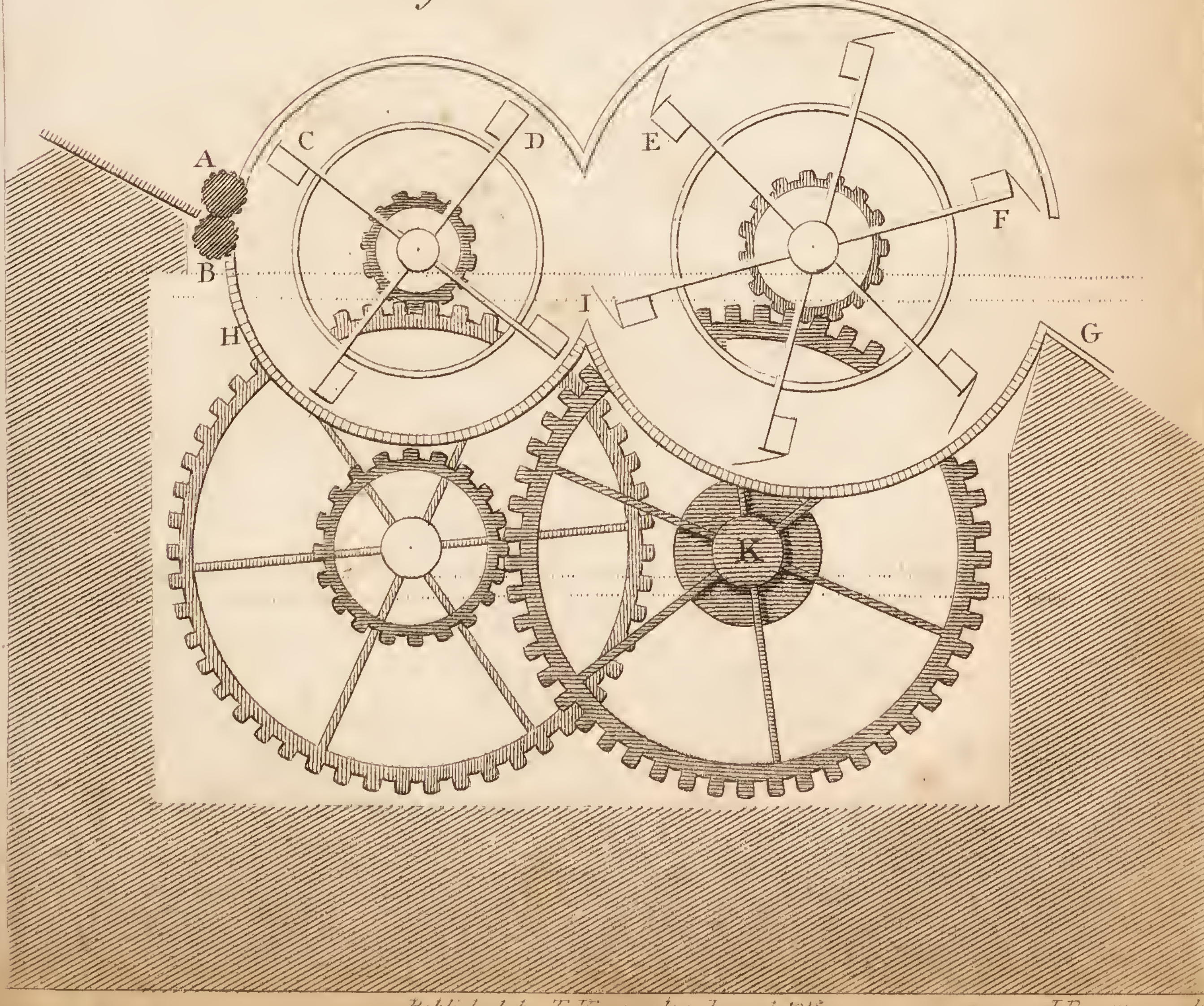


Fig. 3.



Published by T. Kinnersley, June 1.1816 I. Brown, sculpt.

break or crumble down with the water, and so fill up and choak the open spaces between them. When land is very wet, or has not much declivity, there should in general be two main drains, down the slope or fall of the ground, to one acre: for the shorter they are the less are they liable to accidents. The width of the trench for the main drain should be 30 inches at top; but that of the bottom must be governed by the kind of materials to be used in filling it up. When the drain is to be made of large bricks, 10 inches long, 3 inches thick, and 4 broad, the bottom of the drain must be 12 inches: but when common sale bricks are used, the breadth must be proportionably diminished. In both cases an interval of one inch should be left between the bottom brick and the sides of the trench, to be filled up with straw or rushes. It is to be remembered that even in the firmest and hardest ground, as clay or marle, the bottom ought always to be covered with stone or brick as well as in loose soft soil. for no natural bottom will long resist the constant flow of the water, however gentle the current.

Not only stones and bricks, but also wood and other materials are used for filling drains. When filled with wood, and covered with straw or rushes, drains are more serviceable than when filled with stones; for as the wood decays the water still continues to pass without interruption, whereas stones must in time moulder down, forming hard earth which will at length stop all passage for the water. Again, as bushes form a much greater number of cavities than either stones or poles, they encourage filtering more and longer than any more solid materials. For filling drains the *black thorn* has been found, on long experience, to be preferable to any other material. Wood is often used in this manner: two billets are placed leaning with one end on one side of the bottom of the trench, and the other leaning against the opposite top or side, so that the two nearest billets form a St. Andrew's cross, or the letter X. The upper part of the cross is then filled with brush-wood laid lengthwise, with straw cross-wise over it, and the mould covering all. Instances of this drain have been known in Scotland to flow for 30 years. This practice has been introduced into Wales; and on it the author of the report given of the county of Caermarthen to the Board of Agriculture, makes the following remarks. "The completest method of draining, I have yet known, is to cut the strongest willows or other water brush-wood, into lengths of about 20 inches, and to place them alternately in the drain, with one end against one side of the bottom, and the other leaning against the opposite side. Having placed the strong wood in this manner, I fill the space left between them, on the upper side, with the small brush-wood, upon which a few rushes or straw being laid, the work is done. Willow, alder, ash, or beech boughs are exceedingly durable, if put into the drain green, or before the sap is dried; but if they are suffered to become dry, and are then laid in the ground, a rapid decay is the consequence. I have seen willow taken out of a bog, after lying there 30 years, and its bark was as fresh and sappy as if it had been lately cut from the hedge; and it is well known that beech laid green in the water, will continue sound for any length of time."

In many parts a serious obstruction to agriculture arises from the existence of mosses. On the origin of mosses many opposite opinions have been given; but it seems to be this. What are called moss plants amount to about 300 in number. They are extremely hardy, and will

flourish in the coldest, bleakest situations, provided only they have abundance of stagnating water. When these plants have risen to some height, the lower parts of their stems continually soaked in the water, cease to vegetate, and then give out their juices to the water around them. As moss plants are extremely astringent, and contain large quantities of the tanning principle, the water acquires so much of this quality as to prevent all putrefaction in the stems of the plants: and moss water has even been used with advantage in tanning hides, in the same way as oak bark. In the mean time young plants spring up from the tops of the old ones, until the standing water ceases to accompany them, without which they cannot live. In this condition the upper parts of the plants exposed to the air, go through the ordinary process of corruption like other vegetables, and in time are turned into a sort of soil, upon which a few plants and animals are found; while at a small depth below the surface of the stagnating water, the stems and stalks of the original moss plants continue to soak in their own liquor, and are thus preserved from corruption. Mosses are not however always natural productions: they are also produced by human operations. In almost all our mossy grounds great numbers of trees are found, like the lower parts of moss plants, steeped and soaked in the water, but not rotted. The trees found in mosses exhibit perhaps the original sorts produced in this country: in them are found oak, elm, birch, willow, alder, fir, hazel, heath, &c. If it be supposed therefore, that in ancient times forests were cut down and suffered to remain on the ground, particularly in hollow or level situations, a stagnation of water, and bleakness of climate would infallibly ensue, moss plants would spring up and form a *peat bog*, in which multitudes of trees, shrubs, and plants would be preserved in the astringent liquor.

There are two ways in which ground covered with moss may be brought under the plough. The one is to remove altogether the mossy substance, or the whole remains of the plants which have been accumulating for ages, and then to cultivate the under soil. The other is to convert the substance of the moss itself into vegetable mould fit for bearing crops of grain. Where a command of smart running water can be had, the most economical method of getting rid of the moss has been found to carry open drains of good size through the moss, and to throw the substance into the stream, by which it is carried off, and the useful under soil is laid open for cultivation. In improving the mossy surface itself, no application has been found so serviceable as lime spread over the surface. Even in places where the surface of the moss had been pared off and burnt, the grain was by no means equal to what was raised on parts covered with lime, which besides other effects is a most deadly enemy to heath.

In improving a moor in its natural state, it should be opened, if possible, in winter, when it is wet, which has this convenience that the plough cannot then be employed elsewhere. It is here however supposed that the moisture has been previously carried off by draining. In spring, after the frost is gone, a slight harrowing will fill up the interstices with mould, to keep out the air and rot the sod. Thus it may lie during the following summer and winter, which will tend more to rot the turf than if laid open to the air by ploughing. In the ensuing April it should be cross ploughed, braked and harrowed, till it be sufficiently pulverized for turnip-seed, to be sown broadcast or in drills,

after being manured, and the manure well mixed with the soil by repeated harrowings. It sometimes happens however that the heath growing upon a moorish soil is so strong and vigorous as to be very difficult to subdue. In such a case, after land is drained, and the heath is burned upon the surface, the plants may be extirpated by sheep, which are extremely fond of the tender shoots and flowers, but will not touch heath after it has run to seed. The most effectual mode of eradicating heath however is by spreading quick lime over the ground; a strong dose of burning lime therefore laid upon new land, after it is first ploughed, is attended with the best effect, in consuming the roots of heath and coarse grasses, and rendering the soil brittle and free; which effects the lime will produce in half a year. But although a very considerable quantity of lime be necessary upon land newly brought in, yet something more is still requisite: to render the soil permanently fertile it will soon be needful to assist it by vegetable and putrid manure. The turnip crop may be consumed by sheep upon the ground, which will afford excellent preparation for laying it down with grass seeds; a point of great importance to the farmer. It is even said to answer perfectly well to take three or even four crops of turnips in succession, all eaten off in the same way. No manure will be needed for the two succeeding crops; and the soil will be greatly thickened and enriched.

Of different kinds of soil, and the plants proper for each.

It was formerly observed that soils may be divided into *sand, clay,* and *chalk,* with *garden mould,* a compound of the other three.

1. *Clay* is in general the stiffest of soils, and of an unctuous nature: but under the term clay various kinds and colours of earth are included. One sort is so obstinate that scarcely any thing will correct it: another is so poor and hungry that it swallows up whatever is applied, and turns it into its own quality: but in general the fattest clays are the best. All clays however retain the water on their surface, which chills the plants, without sinking into the ground. The closeness of clay also hinders the roots and fibres from spreading out to find nourishment. Blue, red, and white clays, when strong, are unfavourable to vegetation; the stony and loose sorts are less so; but none of them are of any use until their substance is so loosened by a mixture of other materials, and opened so as to admit the sun, the air, and the frost. Among the manures for clay, sand is esteemed the best, especially sea sand, which the most effectually breaks the cohesion of the parts of the clay. The reason for preferring sand from the sea is this, that it is not composed entirely, as other sands are, of small or broken stones and rocks, but contains a great deal of calcareous matter, such as shells broken and pounded down by the action of the tides, winds, and currents, and also a quantity of salt. The smaller or finer the sand, the better it mixes with the clay, but its effects are less durable. Shell marle, ashes, all animal and vegetable substances are useful manure for clay: but they always answer best when mixed with sand. Lime has often been applied to clay; but when alone it is perhaps of no real service.

The crops most suitable for clay soils are wheat, beans, cabbages, ryegrass. Clover seldom succeeds in clay, nor indeed any sort of plant of which the roots require to spread through the soil.

2. *Chalk* is generally a dry and warm soil, and fruitful when there is a tolerable depth of mould; producing abundantly barley, rye, pease, vetches, clover, trefoil, burnet, and particularly sainfoin. When the surface is thin this soil requires good manuring with clay, marle, loam, or dung. As chalk lands are dry they have this advantage that they can be sown earlier than others. When the barley is the height of three inches, throw in 10 pounds of clover or 15 pounds of trefoil, and roll it well. The next summer mow the crop for hay: feed off the aftermath with sheep, and in winter give it a top dressing with dung. This will produce a crop the second spring which should be cut for hay. When this crop is carried off, plough up the land, and in the beginning of September, sow three bushels of rye per acre, either to feed off with sheep in the spring, or to stand for harvest. If it be fed off, then sow winter vetches in August or September, to be made into hay in summer. Then get the land into as fine tilth as possible, and sow it with sainfoin, which with a little manure, once in two or three years, will produce good crops for twenty years together.

3. *Light poor land* seldom produces any thing good, but when well manured. After it is well ploughed sow three bushels of buck-wheat per acre in April or May: when in bloom let the cattle in upon it, for a few days, to eat off the best, and tread down the other: this done, plough in what may remain immediately. This will soon ferment and rot in the ground: then lay it fine, and sow three bushels of rye per acre. If this crop can be got off early enough, sow turnips; if not, sow winter vetches for hay. Then get the land into good tilth, and sow turnip-rooted cabbages in rows 3 feet asunder. This plant will seldom fail, and it will be the best spring feed for cattle, especially if it has been horse-hoed.

4. *Light rich land* being the most easy to cultivate, and capable of bearing most kinds of grain, pulse and herbage, little need be said upon it. It is however to be noticed, that such lands are the fittest for the new or the drill husbandry. This soil, if not given to produce couch grass, is the most proper for lucerne, which in two feet drills, and kept clean, will yield an astonishing quantity of excellent herbage.

5. *Coarse rough land.* Plough deep in antumn, and when it has lain a fortnight, cross-plough, and let it lie rough all winter. In March give it another good ploughing; drag, rake, and harrow it well, to get out the rubbish; then sow four bushels of black oats per acre, if it be a wet soil, but white oats if it be dry. When four inches high roll them well down after a shower, which will break the clods, and the fine mould falling among the plants will greatly promote their growth.

Culture of particular Plants.

The preceding observations are only preparatory to the great business of a farm, which is to raise plants for the nourishment of man, and other animals. These plants are divided into *culmiferous and leguminous.* The culmiferous plants are such as have a smooth jointed stalk, usually hollow, and wrapped about at each joint with single narrow sharp-pointed leaves, and have their seed contained in husks. Wheat, rye, barley, oats, rye-grass, are culmiferous plants. Leguminous plants are those in which the seed is contained in a pod, as pease, beans, vetches, clover, cabbage, &c.

I. Plants are all cultivated for one of three things; for their *fruit*, their *roots*, or their *leaves*. Of those raised for their fruit are,

1. *Wheat and rye*. At any time from the middle of April, to the middle of May, the fallowing for wheat may begin. The time should be chosen when the ground, beginning to dry, has still some remaining softness; for then the soil will readily give way to the plough, and fall into small parts. Ground ploughed very wet rises *whole fur* as it is called, or in great lumps not easily broken down even by after ploughings. A clay soil requires high ridges formed by beginning to plough at the outer furrow, and ending at the crown. This ploughing ought to go as deep as the soil will allow, and water furrowing should follow immediately. About the first week in June the great brake will loosen and reduce the soil, encourage the growth of a second crop of yearly weeds in plenty, if the first ploughing was well done, and bring up to the surface the roots of the weeds loosened by the plough. The second ploughing should come on in the beginning of July, when the weeds are well up; and this should be carried across the ridges, in order to reach all the slips of the former labour. Employ the brake again about the 10th of August to destroy weeds, which is a most important but much neglected point in fallowing. The field is now ready for manure, whether lime or dung, which ought to be directly incorporated with the soil by a repeated harrowing, and a gathering furrow. This will fall in the beginning of September, and the seed should be sown as soon after as can be done.

As in ploughing a clay soil it is of consequence to prevent poaching the ground, the hinting furrows ought to be drawn with two horses in a line.

Loam, or a medium between sand and clay, is the fittest soil for culture, and the least liable to accidents: but it is more subject to weeds, especially couch-grass, than clay; and to destroy these fallowing is still more necessary for loam than for clay.

A sandy soil is too loose for wheat. The only chance for a crop from it is after red clover, the roots of which bind the soil. Rye is much fitter than wheat for a sandy soil; and like wheat it is usually sown after summer fallow.

In general the beginning of October is the best time for sowing wheat: if sown a month earlier it is too forward in the spring, and apt to be hurt by the frost: when much later it has not time to take root sufficient before the frost comes on, which forces it out of the ground.

Setting of wheat is by some reckoned one of the greatest of modern improvements in husbandry. It was first suggested by an experiment in a garden; but about 40 years ago, a small farmer near Norwich, tried it on a larger scale, on near an acre of land. The trial was imitated by only a few of his neighbours: but as their crops were larger, their corn better, and a great saving was made in seed, their example gradually made a powerful impression. It is remarked, that set crops appear thin during autumn and winter, but in the spring the plants side-shoot, and spread out prodigiously. The ears are indisputably larger, without any small dwarfy corn; the grain is larger and heavier per bushel than what comes from sown wheat.

The method of setting wheat is this. The lands on which it succeeds best are either after a clover stubble, or those on which trefoil and grass seeds were sown in the spring before the last. The grounds, after the

usual manuring, are once turned over by the plough, in a long extended flag or turf, at ten inches wide, along which a man called a *dibbler*, with two setting irons, somewhat bigger than ramrods, but considerably thicker at the lower end, and pointed at the extremity, steps backwards along the turf, making holes about four inches asunder, every way, and an inch deep. Into these holes the *droppers*, (women, boys, and girls,) drop two grains of wheat, which is quite sufficient. After this a gate bushed with thorns is drawn by one horse over the land, to close up the holes. By this mode three pecks of grain are sufficient for one acre: and the grain being immediately and completely covered, is equally secured from birds and frost. The regularity with which the wheat rises gives the best opportunity of keeping it clean by weeding or hand-hoeing. This practice is particularly beneficial when wheat is dear. One farmer in Norfolk found the crop when set to be two bushels more upon the acre, than when sown: besides having much less small corn intermixed with it, the sample is better, and always some shillings per quarter better price. This way of setting wheat has this great advantage that it saves to the farmer, and consequently to the public, six pecks of seed on every acre; which if universally adopted in this country would suffice to feed half a million of people. To these considerations we must add the great support afforded to the labouring poor, by this *second* harvest work. The expence of setting an acre has been reduced to ten shillings, which in good weather may be executed by one dibbler and three droppers in two days. This is five shillings per day: and if the dibbler give to each of the three children droppers six-pence, he will still have three shillings and six-pence for his own day's work; much more than he could earn by any other labour so easy to himself. And in the case that a man has a wife to dibble along with him, and two or three of his children to drop, his gains, it is evident, will be prodigious, and sufficient to ensure plenty of hands for the work.

A very important experiment is related in the Philosophical Transactions of the Royal Society of London for 1768, concerning the advantages of propagating wheat, *by dividing and transplanting the roots.*

On the 2d of June 1766, some grains of common red wheat were sown: on the 8th of August a single plant was taken up and separated into 18 parts, when each part was again planted separately. These new plants having pushed out several side-shoots by the middle of September, some of them were taken up and divided, and the rest of them between that time and the middle of October. This second division produced 67 plants. They all remained through the winter, and another division of them, made between the middle of March and the 12th of April, produced 500 plants. No further division was made. The plants were in general stronger than any of the wheat in the fields; some of them produced upwards of 100 ears from a single root: many of the ears measured 7 inches in length; and contained between 60 and 70 grains. The whole number of ears which, by this process, were produced from *one single grain of wheat* was 21,109, yielding 3 pecks, and 3 quarters of clean corn, weighing 47 pounds 7 ounces; and by a calculation founded on the number of grains in one ounce, the whole number of grains must have been about 576,840. By this account it appears that only one general division of plants was made in the spring: had a second been made, the number of plants, it was computed,

would have been *two thousand* instead of five hundred. The ground where this experiment was made was a light blackish soil upon a gravelly bottom, and consequently bad for wheat. One half of it was dunged, and the other half had no manure: there was not, however, any difference discoverable in the strength, growth, or produce of the plants.

On this very curious and interesting scheme it must be evident that, however advantageous in many important points of view, the vast labour and consequent expence attending it on a large scale, and in various parts of the country, must perhaps for ever prevent its being brought into general practice.

Norfolk culture of wheat. Perhaps in no part of the kingdom is wheat cultivated with more care, and brought to more perfection, than in Norfolk. The greatest part is sown upon a second year's ley; sometimes upon a first year's, at others upon summer fallow, or after pease, turnips, buck-wheat, harvested or ploughed down. The second year's leys having brought the stock-cattle and horses through the fore part of summer; and the first year's leys being ready to receive his stock, the farmer begins to break up his old land or ley ground, by a peculiar mode of cultivation called *rice-balking,* in which the furrow is always turned toward the unploughed ground, the edge of the coulter always passing close by the edge of the flag last turned. In this state the leys remain till the end of harvest, when he harrows and afterwards ploughs them across the balks of the former ploughing, bringing them now up to the full depth of the soil. On this ploughing he immediately harrows the manure, ploughing it in with a shallow furrow. Thus the land lies till seed-time, when it is harrowed, rolled, sown, and gathered up into ridges, commonly of six furrows.

In Norfolk, the farmers never begin to sow wheat till after the 17th of October, and continue sowing to the beginning of December, and even later; giving as a reason for this late sowing that wheat treated in this manner is less apt to run to straw than what is sown earlier. The seed is generally prepared with brine, and candied with lime. To prepare the seed they dissolve the salt in a very small quantity of water, barely sufficient for the purpose. The lime is slaked with this brine, and the wheat candied with it in its hottest state, having been previously moistened with pure water. Wheat prepared in this way is found by experience to be more free from *smut* than when any other preparation is employed.

2. *Oats.* Winter-ploughing is a necessary part of the culture of oats. Providence has neglected no region intended for human habitation. In warm climates the soil is meliorated and improved by the heat of the sun: in cold climates it is no less meliorated by frost. Frost acts upon water by swelling and expanding it so as to occupy a larger space. Many a bottle has been burst by the swelling of the frozen liquor within it. Upon earth or sand perfectly dry frost, for this reason, has no effect; but upon wet earth it acts most vigorously, expanding the moisture, which requiring more room, moves all the particles of earth out of their place, and so separates them the one from the other. In this view frost acts infinitely better than any plough that can be made by man: its action reaches the very smallest particles of the soil, particularly in tilled land, which being opened freely admits the frosty air. With respect to clay soils in particular there is no rule more essential

than to open it before winter, in expectation of the frost. It is even advisable in a clay soil to leave the stubble rank; for when it is ploughed in before winter, it keeps the clay loose, and admits the frost into every chink and cranny of the soil.

A loamy soil requires much the same dressing with clay, only that being less injured by wet it does not require high ridges, and therefore ought to be ploughed crown and furrow by turns.

A gravelly soil being the reverse of clay never suffers but from a want of moisture; it should therefore have no ridges, but be ploughed circularly from the centre to the circumference, or from the circumference to the centre. It ought to be tilled after harvest; and the first dry weather in spring should be laid hold of, to sow, harrow, and roll, which will keep it in sap.

The culture of oats is the simplest of all: being probably an original native of Britain, they grow on the worst soil with very little preparation. For this reason, before the introduction of turnips, oats were always the first crop upon land just broken up from a state of nature. Oats are particularly cultivated in the western division of the vale of Yorkshire, where the soil is chiefly a rich sandy loam, unproductive of wheat. Five or six bushels, or even a quarter of oats are sometimes sown upon an acre: the produce being from seven to ten quarters. The market is therefore very great for oats in West Yorkshire; the manufacturing districts there, and in the adjoining parts of Westmoreland, Lancashire, Derbyshire, &c. using principally oaten bread.

In the papers of the Bath Agricultural Society it is recorded that, on a farm near Bristol, the prodigious increase of 98 Winchester bushels was obtained from 4 bushels on the acre. The land was a deep mellow, sandy loam: it had carried potatoes the foregoing year, and received one ploughing for winter fallow. Another ploughing was given in February, and the seed was sown on the 27th and 28th of that month. The striking success of this experiment was supposed to be owing partly to the early sowing, and partly to a good deep tillage.

3. *Barley.* This plant requires a mellow soil: so that extraordinary care is necessary when it is to be sown on clay. The land ought to be stirred immediately after the foregoing crop is removed, that it may be laid open and mellowed by the air and frost. With a view to this effect a peculiar sort of ploughing has been introduced called *ribbing*, by which the greatest surface possible is exposed to the air: but to this method it is objected that by it one half of the ridge is left unmoved. To remedy this great defect, the following method is strongly recommended. As soon as the preceding crop is off the field, let the ridges be gathered with a furrow as deep as the soil will permit, beginning at the crown, and ending at the furrows. Such ploughing loosens the whole soil, and gives free access to the air and frost. Soon after this operation begin a second ploughing in this way. Let the field be divided by parallel lines, thirty feet asunder, across the ridges. Plough once round one of these intervals between the lines, beginning at the edges, and turning over the earth towards the middle of the interval; which will cover a foot or so of the ground formerly ploughed. Within that foot plough another round similar to the former; and so on with other rounds until the whole interval of thirty feet be finished, ending at the middle. Or instead of this the ploughing may begin in the middle of the interval, and end at the edges. As by this work the furrows

of the ridges will be pretty much filled up, let them be cleared and water-furrowed without loss of time. In this way the field is kept perfectly dry; for besides the capital furrows that divide the ridges, every ridge has a number of cross furrows, to carry the rain directly to the former. If the ground be clean, it may lie in this state, through winter and spring to the time of seed-furrowing. If weeds rise, they must be destroyed by ploughing, or breaking, or both; for there can be no worse husbandry than to put the seed into dirty ground.

When land is in good order and free from weeds, the month of April is the most proper for sowing barley, every day from the first to the last. The best soil, according to Norfolk farmers, for barley is that which is dry and healthy, rather light than stiff, but yet of sufficient strength to retain the moisture. On land of this sort the grain is always the best bodied and coloured, the nimblest in the hand, and has the thinnest rind; qualities strongly recommending it to the maltster. If the land be poor it ought at least to be dry and warm: for when so it will bear better corn than richer land in a cold and wet situation.

In choosing seed-corn observe that the best is of a pale lively colour, and brightish cast, without any redness or black tinge at the tail. If the rind be a little shrivelled, it is the better; for that shrivelling proves it to have a thin skin, and to have sweated in the mow. The necessity of changing the seed, and not sowing two years together the barley that grew on the same soil, is in no part of husbandry more evident than in this grain, which if not frequently changed, will grow coarser and coarser every succeeding year.

It has generally been thought that seed-barley is benefited by steeping: but liming has in many instances been found prejudicial. Sprinkling a little soot into the water in which it is steeped has been of great service in securing the seed against insects. In a very dry seed-time, barley that has been wetted for malting, and begins to sprout, will come up sooner, and produce as good a crop as any other.

The county of Norfolk is peculiarly adapted to the cultivation of barley, the strongest soil not being too heavy, and the lightest being able to bear it: and so skilful are the farmers there in its management, that the barley of Norfolk is desired for seed, all over the kingdom. Barley is there sown after wheat or turnips; and in some very light lands it is sown after the second year's ley. After wheat, and the wheat sowing in other parts of the farm being finished, the stubble is trampled down with bullocks, and the land ploughed with a shallow furrow, for barley. In the beginning of March, the land is harrowed, and cross-ploughed. In April it receives another ploughing lengthwise, and at seed-time it is harrowed, rolled and sown, the surface being rendered as smooth and even as possible. After turnips the soil is broken up as fast as the turnips are taken off, if early by *rice-balking* before explained, but if late by a plain ploughing. With respect to barley it is to be remembered, that in its culture so much depends on the nature of the soil, so much on the preparation, so much on the season of sowing, so much on the harvesting, that of corn crops, barley is the most difficult to be cultivated with certainty of success.

4, *Buck-wheat* delights in a mellow sandy soil: but it succeeds well in any dry loose healthy land: a stiff clay is its aversion; and it is entirely lost labour to sow it on wet poachy ground. The proper season for sowing it is in the end of May, or beginning of June. In an ex-

periment upon a small piece of land two crops of buck-wheat were raised in the summer of 1787. After spring-feedings, or a crop of turnip-rooted cabbage or vetches, there will be enough of time to sow buck-wheat. From experiments made in the vicinity of Bath and Bristol, it would seem that the culture of this plant ought, in many cases, to be adopted instead of summer-fallowing: for the crop produced not only appears to be so much clear gain, in respect of that practice, but it affords a considerable quantity of straw for fodder and manure; besides that a summer-fallowing is far from being so advantageous a preparation for a succeeding crop.

5. *Pease.* This plant is of two kinds, the grey and the white: the latter belongs properly to the garden and table: it is with the former that the farmer is chiefly concerned. Of the grey pease there are two sorts, distinguished by their time of ripening. One ripens soon, and is called *hot* seed: the other, which ripens later, is called *cold* seed. Pease, a leguminous crop, comes in very properly between two culmiferous crops, not so much for the value of the pease produced, as for the melioration of the land. In a dry season, pease make good returns; but they are very precarious: hence in a moist climate, such as the western parts of Britain, red clover seems to be more beneficial, as it makes as good winter food as pease, and may be thrice cut green in a summer.

A field intended for cold seed ought to be ploughed in October or November; and in February as soon as the ground is dry, the seed should be sown on the winter furrow. For hot seed the ploughing may be done in March or April, immediately before sowing. Should the ground however be infested with weeds it ought, as in the former case, to be also ploughed up in October or November.

Pease laid a foot below the surface will vegetate, but the best depth is six inches in light soil, and four inches in clay soil: for which reason they ought to be sown under furrow, when the ploughing is delayed till spring. Of all grain, beans excepted, pease are the least in danger of being buried. Pease differ from beans in loving a dry soil, and dry season. Horse-hoeing would be a great advantage: but pease grow fast, and soon fall over on the ground, so as to prevent ploughing. Notwithstanding this a farmer in the south of Scotland began, some time ago, to sow his pease in drills, and never failed to have great crops of grain as well as straw. He sowed double rows a foot asunder, and two feet and a half between the double rows, so as to admit horse-hoeing. In Norfolk leys are seldom ploughed more than once for pease; and the seed is in general dibbled in upon the flag of this single ploughing: but stubbles are generally broken by a winter-fallow of three or four ploughings; the seed being sown broad-cast, and ploughed in about three inches with the last ploughing.

6. *Beans.* The most proper soil for beans is a moist and deep clay: but they may also be raised upon any heavy soil. They are cultivated in two ways, either in the old way by broad-cast, or in the later way by drilling in distinct rows. When the broad-cast is to be used, as beans are sown early, the ground should be ploughed before winter, to admit the air and frost so necessary to clay soils. In February when the weather is dry, loosen the soil with the heavy harrow, to bring on a mould, then sow the seed, and cover it in with the second harrow. The third harrow will smooth the surface, and cover the seed equally As beans delight in a moist soil, and have no end to their growth in

a moist season, they totally cover the ground when sown broad-cast, keep in the dew, exclude the sun and air; consequently the plants grow to a great size, but they bear little seed, and that little is never well ripened. This displays the advantage, and even necessity of drilling beans, which gives free access to the sun and air, dries the surface, and affords plenty of well grown ripe seed.

II. *Plants cultivated for their roots.*

1. *Potatoes.* Next to grain, potatoes may be looked upon as the crop the most generally useful for the husbandman: for they afford a most excellent food, not only for cattle, but for the human species; and they are perhaps the only substitute that could be used for bread, with any prospect of success. The choice of soil is more important in the cultivation of no plant than in that of the potatoe. In clay or rank black loam, lying low without free access to air, potatoes never make palatable food. In a gravelly or sandy soil, exposed to the sun and air, they thrive to perfection, and have the best relish: But a rank black loam, though improper for raising potatoes for the table and human food, produces them in great abundance; and the roots are an acceptable and palatable food for horned cattle, hogs and poultry.

As two great advantages of a drilled crop are the destruction of weeds and the obtaining of a fallow at the same time with the crop, no judicious farmer will now think of raising potatoes in any other way. In September or October, as soon as the year's crop is removed, the field should have a rousing furrow, then a cross-braking, and lastly be cleared of weeds by the cleaning harrow. Form it into three feet ridges, and let it lie till April, which is the proper planting time for potatoes. Cross-brake it to raise the furrows a little, then lay well-digested dung along the furrows, upon which lay the roots at eight inches distance. Cover up these roots with the plough, going once round every row. This makes a warm bed of dung below, and a thin loose covering above, that admits the rays of the sun. As soon as the plants appear above ground, go round every row a second time with the plough, to lay upon the plants an additional inch or two of mould, and at the same time to bury all the annual weeds; this will complete the ridges. When the plants are six inches high, the plough with the deepest furrow should go twice along the middle of each interval, in opposite directions, laying the earth first on one row and next on another: indeed for this purpose a plough with a double mould-board, would be the most expeditious. But as the earth cannot be laid close to the roots by the plough, the spade must next be employed, to cover four inches of the plants. In weeding potatoes, a hoe should never be used, for it cannot go so low as to root out the weeds without at the same time injuring or destroying the fine long fibres of the potatoe, on the growth and extent of which the hopes of a crop depend.

When potatoes are raised as a preparation for wheat, it is best to have the rows two feet two inches from each other, hand-hoeing only the space from plant to plant in each row, then turning a small furrow from the inside of each row, by a common light plow; and afterwards with a double-breasted plough and one horse (to split the ridge formed by the first ploughing,) thoroughly clean the intervals.

Potatoe sets should be cut a week before they are planted, with one

or two eyes to each, and the pieces not very small: two bushels of fresh-slaked lime should be thrown over the surface of the land, as soon as planted, which will effectually prevent the attacks of the grub.

It is of importance to know not only how to raise potatoes, but how to preserve them. When taken out of the ground lay in the corner of the barn a quantity that may serve till April, covered from frost with straw pressed down, bury the rest in a hole dug in the ground, mixed with the husks of dried oats, or sand, or the dry leaves of trees, over which build a stack of hay or corn. When the pit is opened to take out the potatoes, the eyes of such as have a tendency to shoot must be cut out; and this quantity will serve all the month of June. To be still more certain of making the old crop meet the new, the setting of a small quantity of potatoes may be delayed till June; to be taken up at the ordinary time before frost. These not having then arrived at their full maturity when they are taken up, will not be so ready to push as what are set in April.

Should the old crop however be exhausted before the new be quite ready, the interval may be supplied by the potatoes of the new crop, which lie next the surface, to be picked up by the hand; and this far from hurting the coming crop will rather improve it.

Among the variety of modes proposed to prevent the disease among potatoes called the *curl*, the following is lately given in that most useful practical work the *Farmer's Magazine* published periodically at Edinburgh, but sold in all principal towns of the kingdom. A correspondent in that publication says, that, in order to vary the seed, which is considered as the most effectual prevention of the curl, he used what is called *potatoe beans*, a dark brown substance, larger than a horse bean, growing near the ground, on the hulm or stem of the potatoe plant and, as is supposed, occasioned on places where the stem has been broken or injured. These beans are shaped like potatoes, having a number of eyes, from one of which grow two small leaves. Some of these bodies, were planted a few years ago, merely to see if they would grow, when they produced a great number of common sized potatoes, but of a bad quality. These potatoes however being cut in the usual way, and planted next year, produced potatoes of an excellent quality, and in great plenty. They are planted and treated in every respect like the others; and ever since, the cultivator never had occasion for any other change of seed, but what he could raise yearly from the beans.

2. *Turnips* delight in a gravelly soil; and there they are raised to the greatest perfection, and with the least hazard of miscarriage: at the same time there is no soil which will not bear turnips, if it be well prepared. No person ever deserved better of any country than he who first cultivated turnips in the field. No plant is better suited to the climate of Britain, no plant prospers better in the coldest parts of it, none contributes more to fertilize the soil. Of all roots turnips require the finest mould; wherefore of all harrows a good frost is the best. To give access to the frost, the land ought to be prepared by *ribbing* after harvest, as was shown in speaking of barley. If the land be subject to annual weeds, they must be destroyed by braking in April, and again in May. In the first week of June plow the field with a shallow furrow; liming it, if necessary, and harrowing the lime into the soil. Draw single furrows with intervals of three feet, and lay dung in the furrows.

Cover the dung sufficiently by going round it with the plough, and forming the three-feet spaces into ridges. Thus the dung comes to lie below the crown of every ridge. The season of sowing must be regulated by the intended time of feeding; if this be for November, December, January, and February, the sowing should be all the first three weeks of June: if the feeding be for March, April, and May, the sowing need not be done till the end of July. Turnips sown earlier flower that same summer and run to seed, so as to be in a great measure unfit for food: if sown much later they do not apple, and there is no food but from the leaves. Though by a drill plough the seed may be sown of any thickness, yet the safest way is to sow thick; that the crop may stand the ravages of the black fly, and still leave a sufficient crop behind. Thickness of turnips is also a protection against drought, gives the plants a rapid progress, and settles them well in the ground, before it becomes necessary to thin them.

The sowing of turnips in broadcast, almost universal in England, and not yet entirely banished from Scotland, is still a very bad practice. The eminent advantage of turnips is this, that, besides being a profitable crop itself, it makes a most complete fallow: and this last can never be obtained but by horse-hoeing: wherefore the sowing of turnips in rows three feet asunder is recommended. Wider rows are unnecessary, and narrower leave no room for a horse. When the plant is four inches high annual weeds will appear. Then go round every interval with the slightest furrow possible, two inches from each row, moving the earth from the rows towards the middle of the interval. A thin plate of iron should be fixed on the left side of the plough, to keep the earth from falling back, and burying the turnip. Next, let women weed the rows with their fingers, which is better done, and even cheaper than hand-hoeing. The hand-hoe besides is apt to disturb the roots of the turnips that are to stand, and to leave them open to drought, by taking the earth from them. Those that are to stand should be twelve inches asunder in the rows, a distance found to be the most advantageous. In weeding turnips with the fingers, children under thirteen years of age may be employed; above thirteen, hand-hoes suited to their size and powers are excellent implements, both for the work and the labourers; for they strengthen the arms of young persons amazingly. In driving the plough the legs only are exercised: but as the arms are chiefly employed in husbandry, those parts ought to be prepared beforehand, by gentle exercise.

In cultivating turnips care should be taken to procure a good bright nimble well dried seed of the best kind. The Norfolk farmers generally raise the oval white, the large green-topped, and the red or purple-topped kinds, which from long experience they have found to be the most profitable. The seed of turnips, like that of grain, will not do well without frequent changing. Norfolk seed is sent to all parts of the kingdom: but after two years in other quarters it degenerates, so that to have the turnip in perfection, it becomes necessary to get the seed fresh every year from *Norwich:* because *London* seedsmen, knowing its value, have been tempted, it is said, to substitute in its place other inferior seed raised near the metropolis.

The value of turnips as a crop may be estimated from this fact. An acre of land contains 4840 square yards, or 43,560 square feet: suppose then each square yard to contain only one turnip, and that on

an average each turnip should weigh only two pounds: here will be a mess of food of an excellent nature, amounting to 46 tons weight on one acre, and worth from four to six guineas. Extraordinary crops of barley frequently succeed turnips, when properly fed off the land, by confining the cattle with hurdles to as much as is sufficient for them for one day. For then the crop is eaten clean, nothing is spoiled by their feet, and the soil is equally trodden down and manured.

A very erroneous notion prevails that mutton fattened with turnips is rank, and ill tasted: on the contrary it is only upon rank pastures, and marshy lands that rank mutton is produced.

To preserve turnips for late spring seed, the best method is to stack them up in dry straw, one load of which is sufficient to preserve 40 tons of turnips: it is done in this way. After drawing your turnips in February, cut off the tap roots and tops, (which may be given to sheep,) and let them lie a few days in the field, as no weather will then hurt them. Then on a layer of straw next the ground place a layer of turnips two feet thick, then another layer of straw, and again one of turnips alternately, until you bring the heap to a point at the top; taking care to turn up the edges of the layers of straw, to keep the turnips from rolling out: cover the top well with long straw hanging down, to serve as a thatch to the whole. In this way the dry straw sucks up the moisture rising from the roots, and all vegetation is prevented; and the turnips will be nearly as good in May, as they were when first drawn from the ground. To prevent all this trouble and expence, however, farmers would find it their interest to continue sowing turnips on to the latter end of August; by which means their late crops would remain good in the field till the end of April, and often till the middle of May.

On the comparative advantage of different vegetables for feeding sheep the following remarks are given by the Bath Agricultural Society. "When sheep are allowed as many turnips as they can eat, (which should always be the case when they are fattening,) they will, on an average, eat near 20 pounds each in 24 hours. An acre of turnips twice hoed will, if the land be good, produce about 50 tons, which will maintain 100 sheep 52 days. The sheep here mentioned weighed 20 pounds a quarter. An acre of turnip-rooted cabbages will maintain 100 sheep for a month, and sometimes five weeks: but an acre of Scotch cabbages will maintain 200 sheep a full month."

The greatest disadvantage of a crop of turnips is that they are so ready to be damaged by the fly, which sometimes destroys them so completely as to require the field being sown over again twice, and even thrice, in the season. Innumerable methods of avoiding this evil have been prepared, which may all be comprehended under these heads. 1. Steeping the seed in various liquids. 2. Fumigating the fields with the smoke of certain herbs. 3. Rolling, and 4. Strewing soot, lime, ashes, &c. over the ground. It is however very difficult to determine, whether these applications are really of any use: because sometimes the turnips are not injured, though no preparation is used, and when this happens after preparations, the effect is generally, but perhaps untruly, attributed to the preparation. From a number of experiments on steeping the seed, it was found that such as was steeped in linseed and train oils was much more free from the fly, than the other seed steeped in other substances. Fumigation has perhaps never been tried on a large

scale: nor in fact does it at all seem practicable in that way. Little utility can be expected from either rolling or the strewing of substances over the ground. The only methods that promise to be really useful are to sow the turnip so early as that the plants may be well grown, before the fly make its appearance, and to sow such a quantity of seed as will be more than sufficient for the consumption of the insect.

3. *Carrots.* Of all roots carrots require the deepest soil, which ought to be all good for the depth of a foot at least. If the farm contain no such ground, it may be made artificially, by trench-ploughing, which brings up to the surface the soil which never before had any communication with the sun or the air: and this soil improved by a crop or two with dung, will be fit for growing carrots. It is to be remembered that no dung whatever should be laid on, the year in which the carrots are sown, for in that case they would seldom escape rotten scabs. The only soils for carrots are loam and sandy ground. The ground must be prepared with the deepest furrow possible, the sooner after harvest the better; immediately on the back of which a *ribbing* should follow as for barley. At the end of March or beginning of April, which is the time of sowing the seed, the ground must be smoothed with a brake. Sow the seed in drills, with intervals of a foot for hand-hoeing, when the ground is small, but with intervals of three feet for horse-hoeing when the field is extensive; because in that case hand-hoeing would become too expensive. Carrots have been greatly recommended as food for cattle, and in this respect they bid fair to rival potatoes; but for human food they are much inferior. As a substitute for oats to horses the use of carrots is every day gaining ground. By the quantity of sugar they contain, they are probably very rich, and stimulating to the stomach of that delicate animal, so that a less quantity of it goes to waste than of any other food. The use of carrots in the dairy is thus described by an experienced farmer of Essex. "In our dairies as many carrots are bruised before churning, as produce (when squeezed through a cloth into as much cream as makes eight or ten pounds of butter,) a half pint of juice. This adds somewhat to the colour, richness, and flavour of winter butter: and we think, where hay is allowed besides, contributes much to counteracting the flavour from the seed of turnips. At present (our carrot seed being exhausted,) from turnips and hay, with this juice, our butter is equal to that of the Epping dairies."

4. *Parsnips.* This root has never, in this country, received from husbandmen the attention to which it is well entitled, from the ease with which it is cultivated, and the great quantity of saccharine or nourishing matter it contains, in a much greater proportion than in almost any other vegetable with which we are acquainted. To cultivate parsnips, so as to make them advantageous to the farmer, it will be right to sow the seed in the autumn, immediately after it is ripe. By this course the plants will appear early in the spring, and get strong before the weeds can rise to injure them. Neither the seeds nor the young plants are much injured by frost, on which account, as well as many others, the autumn sowing is preferred to the spring. The best soil for parsnips is a rich deep loam; and next to this is sand. They thrive well in a black gritty soil; but not in stone-brash, gravel, or clay: they are always largest in the deepest earth. When the soil is proper they require little manure. The seed may be sown in drills 18 inches asunder, that the plants may be hand or horse-hoed: and they will be more

luxuriant if they undergo a second hoeing, and are carefully earthed, so as not to cover the leaves. Parsnips ought not to be planted by dibbling, as the ground becomes so bound as seldom to admit the small side-fibres to fix in it, and so prevents the root from coming to its proper size. The same remark is applicable to the dibbling of carrots. Parsnips, if not superior, are at least equal to carrots, for fattening pigs, as they make the flesh whiter, and the animals themselves are more fond of them than of carrots. Horses eat parsnips greedily, when clean washed and sliced down among bran, and thrive well upon them: black cattle likewise eat them with relish. In the British island *Jersey*, on the coast of France, parsnips have long been considered of the highest importance. There they have been known for centuries past, and they are preferred by the inhabitants to every other root for fattening cattle and pigs. The cattle fed on them yield a juicy delicious meat: the pork and beef of Jersey are among the best in Europe: and it is remarked that the beef is always best in those months of the year when the cattle feed on parsnips. Cows fed with hay and parsnips in winter give butter of a fine yellow hue, of a saffron tinge, and as excellent as if they fed on the most luxuriant pasture.

III. *Plants cultivated for leaves, or for both leaves and roots.*

1. *Turnip-rooted cabbage* may be reckoned the next in value to the turnip itself; because it affords food for cattle late in the spring, and resists mildew and frost. In the first or second weeks of June, the same quantity of seed is sown, the plants are hoed at the same size, they are left at the same distance from each other, and they are treated in every respect as if the crop consisted of turnips. To raise the turnip-rooted cabbage for transplanting, the best way is to breast-plough and burn as much old pasture as may be judged necessary for the seed-bed: two perches well stocked with plants will be sufficient to plant an acre. The land should be dug as shallow as possible, turning the ashes in, and the seed should be sown in the beginning of April. The land intended for the plantation is to be cultivated and dunged, as for the common turnip. About midsummer, or sooner if the weather be favourable, is a proper time for planting. The land is thrown into *one-bout* ridges, upon the tops of which the plants are set, at about 18 inches asunder from each other. As the weeds rise hand-hoeing is used: afterwards a plough is run through the intervals, fetching a furrow from each ridge, which after lying a fortnight or three weeks, is again thrown back to the ridges. Should the young plants in the seed-bed be attacked by the fly, wood-ashes thrown over them will effectually prevent their ravages. By an experiment made it was discovered that a turnip-rooted cabbage, measuring 18 inches round, weighed $5\frac{1}{4}$ pounds, and a common turnip of the same girth weighed only $3\frac{1}{2}$ pounds. This experiment was made in March: but had the roots been weighed at Christmas, the difference would not have been so great; and this is one of the advantages of the cabbage, that it keeps its juices, and nourishing qualities for a much longer time than perhaps any other vegetable.

2. *Swedish turnip, or roota baga.* Great expectations have been formed upon this plant; which is said to be hardier and of greater sweetness and solidity than the common turnip. It also preserves its

freshness, and juiciness to a very late period of its growth, even after it has produced seed. This peculiarity has been doubted by many, and not without reason; but its reality seems now to be sufficiently ascertained by trials. One person who tried the Swedish turnip, says, it begins to send out its flower-stems in the spring, nearly about the same time with the common turnip; but the root, notwithstanding that change in the state of the plant, suffers very little alteration. "I continued to use these turnips," says he, "at my table every day till toward the middle of May; and had I never gone into the garden myself, I should not even then have suspected, from the taste or appearance of the bulb itself, that it had been shot at all. The stems however, at the season when I gave over using the turnip, were from four to five feet high, and in full flower. The most profitable way of consuming this plant, where it is to be kept very late, I am convinced would be to cut off the tops with a scythe or sickle, when from 12 to 18 inches high, to induce the plant to send out fresh stems, that will continue soft and succulent to the end, whereas without this process the stems become sticky and useless."

3. *Turnip Cabbage* is a plant yet but little known; and has a much nearer relation to the cabbage than to the turnip. The seed came originally from the Cape of Good Hope, from whence the Dutch drew it long ago. It is a very hardy plant, bearing our winters as well, not to say better, than our common broccoli, and may therefore be regarded as a valuable acquisition to the kitchen garden as well as for cattle. The best time for sowing it for the garden is the end of May, or the beginning of June, though none of the plants have ever been observed to run to seed, though sown ever so early. Even when sown in August, the greater part stand throughout all the following summer, and do not seed till the second spring. The bulb is inclosed in a thick fibrous rind: but it has been found that sheep not only penetrated through this hard tough rind to get at the turnip, but even devoured the greatest part of the rind itself.

4. *Cabbage* has by long experience been recommended as an excellent food for cattle. Its uses as human food are too well known to need any recommendation. Cabbage is easily raised, it is subject to few diseases, resists frost better than turnip, is palatable to cattle, and sooner fills them than turnip, carrot, or potatoe. If cabbage be intended for feeding cattle in November, December, and January, plants from seed sown in the end of July the preceding year, must be set in March or April. If for feeding in March, April, and May, the plants must be set the first week of the foregoing July, from seed sown in the end of February, or the beginning of March of the same year. The late setting of the plants keeps back their growth, so that they shoot out vigorously in the following spring.

In one of the papers of the Bath Society, Scotch cabbages are compared, as to their utility in feeding cattle, with turnips, turnip-rooted cabbage, and carrots. In this trial the Scotch cabbages stood next in value to carrots: with this advantage that, if they be of the true flat-topped firm kind, they are not liable to be affected by frost. No less a quantity than 54 tons have been raised upon one acre of land, not worth more than 12 shillings. There is a particular advantage attending the feeding of cattle with cabbages, which is that the manure from them is much more in proportion than when cattle are fed on turnips which

run most to water, or on hay which has too little moisture. Cabbages also impoverish the ground much less than grain. Cabbages may also be planted, without any fresh ploughing, on lands where a late crop of turnips has failed.

Cabbages and greens in general are liable to be infested with caterpillars: they may, however, be protected against vermin by taking off the large undermost leaves, to be given to cows in August, or when the large white butterflies begin to appear in numbers, which deposit their eggs on the under side of the largest leaves of the plant. Another remedy is said to be useful, which is to sow beans among the cabbages; for it is believed that butterflies have an antipathy to the flavour of beans, and will therefore avoid cabbages planted near them.

5. *The root of scarcity, or betacicla,* delights in a rich loamy land well dunged. It should be sown in rows or broadcast, and when the plants are the size of a goose quill, transplanted in rows 18 inches asunder, and 18 inches between the plants in the row. The best time for sowing is from the beginning of March to the middle of April; it is however advisable to continue the sowing every month to the beginning of July, in order to have a succession of plants. Of this plant, both leaves and roots are praised as excellent for both beast and man: it is said also not to be liable like turnips to be destroyed by insects. Horned cattle, horses, pigs, and poultry are exceedingly fond of it when cut small. The leaves may be gathered every 12 or 15 days: they are from 30 to 40 inches long, and from 22 to 25 inches broad. It is excellent for milch cows, when given in due proportion, as it adds much to the quality, as well as the quantity of the milk: but care must be taken to proportion the leaves with other green food, otherwise it will abate the milk, and fatten the cows too much, it being of an exceedingly fattening nature. What the due proportion is, however, has not yet been accurately ascertained by proper experiments.

Culture of Grasses.

On a branch of agriculture so extensive, as well as important, it would be idle to attempt, in our narrow bounds, to give any detailed observations: all that can be done therefore is to lay before the young husbandman a few general remarks and advices, on the art of making and improving lands, for the use of cattle of all sorts.

The latter end of August, or the beginning of September is the best season for sowing grass seeds, as there is then time for the roots of the young plants to fix themselves in the ground, before the frost set in. It is scarcely necessary to say, that moist weather is the best for sowing grass seeds, as the weather being then warm they will vegetate immediately: but if this season prove unfavourable, the sowing may be deferred till the middle of March following.

If you would have fine pasture never sow on foul land; on the contrary plough it well and clear it from the roots of couch-grass, rest-harrow, fern, broom, and all other noxious weeds. Rake them up in heaps to be burnt on the land, and spread the ashes as manure. These ploughings and harrowings should be repeated in dry weather; and if the soil be clayey and wet, make some under-drains to carry off the water, which, if suffered to remain, will not only chill the grass but

make it sour. Before sowing, lay the land as even, level, and fine as possible. With clean seed, three bushels will be sufficient for an acre: and when sown, harrow it gently, and roll it with a wooden roller. When the grass comes up fill up all the bare spots with fresh seed, which if rolled to fix it, will soon come up and overtake the rest. In Norfolk they sow clover with their grasses, particularly with rye-grass; but this should not be done, excepting when the land is designed for grass, for three or four years only, because neither of these kinds will last long in the ground. Where the grass is intended for a continuance it is better to mix only small white Dutch clover or marl grass with the grass seed, not more than 8 pounds to an acre. These are abiding plants; they spread close on the surface, and make the sweetest feed of any for cattle. In the following spring root up thistles, hemlock, or any large plants that appear. If you do this while the ground is soft enough to allow those plants to be drawn up root and all, infinite after trouble will be saved.

The common method of laying down fields for grass is extremely injudicious. Some sow barley with their grasses, which they suppose will be useful in shading them, without considering how much the corn draws away the nourishment from the land. Others take their seeds from a foul hay-rick, by which course, besides filling the land with rubbish and weeds, the seed intended for a dry soil may have come from a moist soil where it grew naturally, or the contrary. The consequence of this is that the ground, instead of being covered with a good thick sward, is filled with plants foreign to its nature.

The kinds of grass most eligible for pasture lands are the annual meadow, creeping, and fine bent, fox-tail, and crested dog's-tail, the *poas* or Suffolk grass, the fescues, the vernal oat-grass, the ray or rye-grass. It is not however advisable to sow all these kinds together; for not to insist on the circumstance that they come to maturity at different times, and therefore never can all be cut in equal perfection and full vigour, no kind of cattle are equally fond of all these sorts. Horses will scarcely touch such hay as oxen and cows would thrive upon: sheep are particularly fond of some sorts and steadily refuse others: darnel-grass, if not cut before several of the other kinds are ripe, becomes so hard and wiry in the stalk, that few cattle care to meddle with it.

Pasture land is of such importance in husbandry, that many would prefer it to corn land, because of the small hazard and labour attending its management, and because it lays the foundation for most of the profit expected from arable land, on account of the manure afforded by the cattle fed upon the pastures. Pasture land is of two sorts, the one meadow land, often overflowed, and the other upland, which is high and dry. The meadow land will produce a greater quantity of hay than the upland, without requiring so frequent manuring and dressing: but then the upland hay is by far preferable to the meadow hay. The meat fed on upland hay is also more valued than that fatted on meadow hay, however rich, although the latter will produce the larger and fatter cattle, as is seen by those brought from the low rich lands in Lincolnshire, and other districts of the same nature. People of delicate taste will always give a much larger price for meat fed on downs, or short upland pastures, than for that fattened in the richest meadows.

Upland pastures. The first improvement of upland pastures is to fence them, dividing them into fields of different sizes, from 4 to 10

acres each, planting timber trees in the hedge-rows, to screen the grass from the dry pinching winds of March, which often prevent the grass from growing in large open lands; so that if April prove a dry month, very little hay is produced. But in sheltered fields the grass will begin to grow early in March, and will cover the ground and prevent the sun from parching the roots. In fencing land, however, very small inclosures ought to be avoided, especially when trees are planted in the hedges; for these when grown up will spread over the land, and often sour the grass.

The next improvement of upland pasture is to make the turf good, where either from badness of the soil, or from want of care, the grass has been destroyed by rushes, bushes, or mole-hills. Where the surface is clayey and cold, it may be improved by paring and burning: but if it be a hot sandy land, then chalk, lime, marl, or clay are very proper manures to lay on it: but in pretty large quantities, or they will be of little service. If the ground be over-run with rushes or bushes, it will be of great advantage to grub them up in the latter part of summer, and after they are dried to burn them, and spread the ashes over the ground, just before the autumnal rains, when the surface should be levelled, and sown with grass seed, which will make good grass in the ensuing spring. Mole-hills should also be pared off, and either burnt for ashes, or spread immediately over the ground, sowing the bare spots with grass when the rains of autumn begin. When land has been thus managed, it should be rolled in February and March with a heavy wooden roller in moist weather, that it may make an impression. This will level the ground, and fit it for proper mowing: it will also make the turf to thicken and gain a good bottom; besides that the grass will be sweeter and weeds will be less apt to spring.

Another improvement of upland pastures is the feeding on them: for where this is not practised they must be manured at least every third year; and where a farmer has much arable land he will not care to part with his manure for the pasture.

Red clover grows luxuriantly on a rich soil, whether clay, loam, or gravel; it will grow even upon moor when properly cultivated; a wet soil is its destruction. To have red clover in perfection, weeds must be banished, and stones taken off. The mould ought to be as fine as harrowing can make it, and the surface smoothed with a light roller, which enables the farmer to sow his seed equally and evenly, to be covered in by a small harrow with teeth no larger than those of a garden rake, three inches long, and six asunder. The proper season for sowing red clover, is from the middle of April to the middle of May. It will spring indeed at any time from the first of March to the end of August: but such freedoms with the seed should never be used, but from necessity. Some fanciful writers talk of sowing an acre of land with *four* pounds of seed: but it is an egregious error to be sparing of clover seed. Grass seeds in general cannot be sown too thick, for the plants shelter one another, they retain all the dew, and when close they must push upwards, having no room to push sidewise. When red clover is sown for cutting green, an acre of land ought never to have less than 24 pounds of seed; for the thicker the clover, the smaller and themore delicate will be the stem, and the more acceptable to the cattle.

Grain may be more safely sown with red clover than with almost any

other grass; and the most proper grain has been found to be flax: for the soil must be equally well cultivated for both these plants. Next to flax, barley is the best companion to clover, for the clover is well established in the ground, before it is overtopped by the barley. And as barley is cut in general sooner than either oats or wheat, it is rather a nurse than a stepmother to the clover.

White clover, yellow clover, ribwort, rye-grass, are cultivated in general in the same way with red clover. Rye-grass is less hurt by frosts than any of the clovers, and will thrive in a moister soil; nor in that soil is it much affected by drought. These grasses are generally sown with red clover, to produce a plentiful crop.

Sainfoin is reckoned, by writers on agriculture, as preferable to clover in many respects: they say it produces a larger crop, that it does not hurt cattle when eaten green, that it makes better hay, that it continues four times longer in the ground, and that it will grow on land that will bear no other crop. Sainfoin has a very long tap-root, able to pierce very hard earth. The larger the roots the deeper they go; and hence it may be concluded that this grass, when it thrives well, draws a great part of its nourishment from below the *staple* of the soil; and of course that a deep dry soil is the best for sainfoin. To make sainfoin vigorous it should be sown thin, and the best way to do this is by a drill. Sainfoin takes several years to come to its full strength, and the number of plants sufficient to stock a field will, while in this imperfect state, make but a poor crop for the first year or two. It should therefore be so sown, that plants may be easily taken up, in such numbers and in such order as always to leave in the field the proper number in their proper places.

Plants taken up from a sainfoin field may be transplanted to other ground to great advantage. In transplanting, a great part of the long tap-root should be cut off, to prevent it from striking very deep in the new soil, and make it push out large roots in a sloping direction from the cut end. Managed in this manner, sainfoin will thrive on even shallow land that has a wet bottom, provided it be not overstocked with plants.

March and the beginning of April are the best seasons for sowing sainfoin, which answers best when drilled, especially on land made fine by repeated ploughing, rolling and harrowing. If cut just before the bloom, sainfoin affords admirable food for horned cattle, and will give a second crop the same season; but if the season be wet, it will be better to let it stand till the bloom be perfect, lest in making it into hay the flowers drop off, of which cows are particularly fond; and it requires more time than any other hay in drying. It is so excellent fodder for horses, that they require no oats while they eat it, although worked hard all the time. Sheep will also fatten upon it sooner than upon any other food. An acre of very ordinary land, when improved by sainfoin, will maintain four cows very well, from the first of April to the end of November, and afford besides a sufficient store of hay to make the greater part of their food for the four remaining months of the year. If the soil be good, a field of sainfoin will last in prime from fifteen to twenty years: but at the end of seven or eight years it will be necessary to lay on a moderate coat of well-rotted dung, or of marl if the soil be very light and sandy. Hence it appears that, for poor land, nothing equals sainfoin, in point of advantage to the farmer.

Lucerne has received the highest commendations from both ancients and moderns, as affording excellent hay, and producing very large crops: it will remain at least ten or twelve years in the ground, and produce seven or eight tuns of hay on the acre. Lucerne should be raised in nursery-beds, and transplanted to the field: part of the tap-root is then cut off, which makes the plant send out a number of lateral branches from the cut part of the root, and so fit it for growth in a shallow soil, where without that operation it would not grow. Lucerne has been transplanted into beds three feet broad, having one row of plants in each bed, in other beds three feet nine inches wide with double rows of plants, and in beds four feet three inches wide with triple rows. The plants in the single rows were six inches asunder, and those in the double and triple rowed beds were eight or nine inches asunder. In the course of three years it was found that a single row produced more than a triple row of the same length. The beds or ridges ought to be raised in the middle, a small trench three inches deep, drawn in the middle, and the plants should be set in this trench, and covered up to the neck with earth. If lucerne be sown in the spring, in a warm soil, it will be ready for transplanting in September: but if the weather be very hot and dry the transplanting should be deferred till October. During the whole time the plant is in a growing state, the intervals between the rows should be stirred carefully once a month by horse-hoeing.

Burnet is peculiarly adapted to poor land: and besides this property it furnishes excellent winter-pasture when hardly any thing else grows. Its other good qualities are that it makes good butter, never swells or blows cattle, is fine pasture for sheep, and flourishes well on poor light sandy or stony soils, or even on dry chalk hills. If the land be prepared as for turnips, burnet will not fail: and after the first year it is attended with very little expence, as the flat circular growth of its leaves will keep down, if they do not altogether prevent the growth of weeds. On the failure of turnips from the fly or the black worm, some farmers have sown burnet on the land, and in the following March have had fine pasture for their sheep and lambs. It perfects its seed twice in one summer, and this seed is said to be as good as oats for horses: but it is too valuable to be applied to that use. It is sometimes sown late in spring with oats and barley, and succeeds very well: but it is best to sow it by itself in the beginning of July, when there is a prospect of rain, on a small piece of ground, and in October following transplant it in rows two feet apart, and a foot asunder in the rows. After it is fed down with cattle, the burnet should be harrowed clean. Some horses will not eat it freely at first; but in a few days they generally grow fond of it: it affords rich pleasant milk, and in great plenty. A farmer in Kent some years ago, sowed four acres with lucerne, as soon as a crop of oats was taken off, which was in the end of August. He threw in 12 pounds of seed on each acre, broad-cast: but no rain falling until the middle of September, the plants did not appear before the latter end of that month. The crop however was good, and in the spring he set out the plants with a turnip hoe, leaving them about a foot distant from each other. Notwithstanding the success of this experiment the drill method is to be preferred, as it saves more than half the seed. The land on which the experiment was made was a poor dry gravel, not worth three shillings an acre for any thing else. The seve-

rest frost never injures burnet; and the oftener it is fed down, the thicker are the leaves which always spring from the root.

The *poa annua*, or annual meadow grass, is said to make the finest of turfs; it grows every where by way sides, and on rich sound commons, it is called in some parts Suffolk grass, because whole fields of it are seen in that county, without the intermixture of any other grass: and as some of the best salt butter used in London comes from that quarter, it is very probable that that sort of grass is the best for the dairy. Thriving particularly well when trodden under foot, as in paths and walks, it would no doubt be greatly improved by repeated rolling.

Meadow pasture. One of the most important improvements in husbandry, introduced of late years, is the overflowing or flooding of grass lands, which is now come into general use, not in low level grounds only, but in all other situations where a command of water can be obtained. It appears however that watering of meadows was practised even in the reigns of Queen Elizabeth, and King James the First. A book was written upon the subject by Rowland Vaughan, who seems to have been the first to employ this method, and who carried it on to a great extent in Golden Valley in Herefordshire. In Switzerland, and in the countries extending on both sides of the Alps in Germany and Italy, the watering of meadows, and even of the pastures upon the steep slopes of the mountains, by means of multitudes of small channels conducted in zigzags from the torrents on their sides, has been in constant use, for time out of mind.

The advantages of watering meadows are many and great, not only as excellent crops of grass are raised by it, but as they appear so early as to be of infinite service to the farmer for food to his cattle, in the spring, before the natural grass rise. The good effects of grass raised in this way are astonishing, especially upon such cattle as have been hardly off through the winter. In Gloucestershire, the farmers who have an opportunity of watering their lands, are able to begin to make cheese at least a month earlier than those who have not that advantage. Grass raised by watering is found to be admirable for bringing up lambs, not only for fattening but for store: for lambs stopped and stinted in their growth when very young, not only become contracted themselves for life, but in some measure communicate the same puny diminutive size to their offspring. The best remedy for preventing this evil is the spring feed from watered meadows.

Land treated by watering is in a constant state of improvement in quality, even though it should be mown every year: the herbage, if at first coarse becomes finer, the soil if swampy becomes sound, the depth of the mould is regularly increased, and its quality meliorated every year. To these advantages another may be suggested, which is that the proprietor who wishes to improve his estate, at the same time furnishes the best of all alms-deeds, namely labour, to the honest and industrious poor, instead of support too often afforded to idleness and vice in the workhouse. In the operations of watering lands almost the whole expence consists in the actual hand-labour of a class of people who have either no genius, or no means for employing their bodily strength in any other way, for the maintenance of themselves and their families. When viewed in this light the expence of watering can be but comparatively small, and the benefits arising from it are great and important.

As a proof of this assertion, the reader will not be displeased to peruse the following facts. A meadow near South Cerney, in Gloucestershire, had been watered longer than the oldest person in the vicinity could remember, but was by no means the best meadow watered by the same stream; nor was the winter preceding the time of observation favourable for watering. It contained six acres and a half. The spring feed was let for seven guineas, and it supported two hundred sheep, from the 1st of March to the beginning of May: the hay being sold for thirty guineas and the aftermath for six. Another still more remarkable proof of the utility of watering was, that two of the most skilful watering-men of the same quarter were sent to lay out a meadow of seven acres, the whole crop of which, for that year was sold for forty shillings. Though it was thought by many to be impossible to throw the water over it, yet the skill of the workmen soon overcame all difficulties: and ever since that time the meadow has been let at the rent of three pounds per acre, in all L.21. instead of L.2. for the whole.

There are three kinds of soil commonly found near rivers and rivulets, the melioration of which may be attempted by watering, namely, 1st, a gravelly, or a sound, firm, warm soil, or a mixture of the two together. Such a soil receives an almost instantaneous improvement, and the faster the water runs over it the better: 2d, boggy, miry, and rushy soils, commonly found by the sides of streams when the banks are low and level. These soils also are greatly improved by watering; perhaps equally so with the former description of soils, if we compare the values of both in their unimproved state, this last kind of land being of little or no worth until improved. By proper watering, however, these second soils may be made to produce large crops of hay, on which horned cattle may be kept through the winter, and greatly forwarded; though in their uncultivated state they would scarcely produce any thing to maintain the stock in the winter, and very little even in summer. Much more skill as well as expence, however, is necessary to bring boggy, miry, and rushy soils, into proper culture, than gravelly or sound warm soils. 3d, The soils the most difficult to improve are strong, wet, and clay soils; and this difficulty is caused by their lying commonly on a dead level, which will not allow the water to run over them, and by their tenacity, which does not admit of their being drained. Even when the utmost care is used, unless a strong body of water be thrown over them, and that from a river, the waters of which have a very fertilizing property, little advantage will be gained: but wherever these advantages can be obtained in the winter, and a warm spring succeeds, these strong, wet and clay lands will produce very large crops of grass.

The advantages of using springs and rivulets for watering instead of large rivers is, that the expense of raising wares to stop their course will not be great; nor are they liable to other objections which attend the use of large rivers. When these rivulets run through a cultivated country also, the land-floods occasioned by violent rains frequently bring down with them such quantities of manure as greatly contribute to fertilize the lands over which they pass; all which materials are entirely lost where watering is not practised.

In watering care must be taken that the water never stand still or stagnate upon the ground, for, in even the swiftest course over the land, the water has always abundance of time to deposit the mud or other fertilizing particles with which it is more or less loaded. And

hence may be seen the reason why water that has been made to flood one tract of meadow so as to fertilize it, is observed to be of no service whatever to another tract of similar land lower down the course of the stream; if, from a mistaken economy, the same water should be carried over two adjoining meadows of considerable extent. That it is the muddy particles carried along by the greater number of streams, and by all after heavy and lasting falls of rain, which produce the chief benefit derived from watering lands, is fully evinced by the uniform operations of nature upon lands exposed to be laid under water by the great rivers in the warmer regions of the earth. The fertility of the long narrow vale of the Nile, stretching the whole length of Egypt, is proverbial. Swelled by the rains that fall far to the southward in the interior of Africa, the Nile in Egypt begins to rise in May, and continues so to do to the beginning of August, when it has in general increased sixteen cubits, or twenty four feet above its usual level. At this time openings are made in the banks and mounds which line its channel, and the waters are conducted or suffered to flow all over the level plain on each side of the river. When the waters retire they leave behind them a thick body of mud, so rich and fertile, that the corn and other seeds thrown upon it produce crops of the most extraordinary increase. On the northern coast of South America, near the mouth of that prodigious body of running water, the river of the Amazons, of the great river Oronoko, &c. similar effects are produced by natural flooding or periodical inundations. The land in what was once Dutch Guiana, or the territories of Surinam, Essequibo, &c. on that coast, for a space of fifty miles back from the sea, is every where flat and level, without a single hill; and so low, that during the rainy season, it is usually covered with water nearly two feet in height. But this has produced an effect similar to that of the prolific inundations of the Nile, and rendered the soil more fertile than that perhaps of any other part of the globe. So much is this the case, that the soil, to the depth of twelve inches, is a layer of the richest and most perfect manure; and as such, quantities of it were once carried to recruit the scorched and exhausted fields of the island of Barbadoes: but the wood-ants, which in Guiana are very numerous, and had been embarked with the soil, committed such ravages in the ship, that the experiment was not repeated. To convey some idea of the fertility of this territory it will be enough to mention that, on the banks of the rivers towards their mouths, *thirty* crops of sugar-canes have been produced successively without replanting; whereas, in the neighbouring islands of the West Indies, more than *two* crops without replanting are never expected. The redundant fertility of those tracts is so great as to be even disadvantageous; so that the inhabitants are obliged to recur to various expedients to diminish the excessive richness of the soil, by plantations of fruits and vegetables the most powerful in impoverishing the ground.

The following general directions respecting the watering of meadows are given by *Mr. Boswell* in his treatise on the subject, published in 1790: " Lands requiring, and capable of watering, lie sometimes all on one side, and sometimes on both sides of the stream, designed to supply them with water. In the former case, when they have a pretty quick descent, the lands may often be watered by a main channel drawn out of the stream itself, without the expense of any ware or dam. Boggy lands require more and longer continued watering than such as are sandy or gravelly; and the larger the body of water that can be brought upon

them the better. *The weight and strength of the water will greatly assist in compressing the soil,* and destroying the roots of the weeds that grow upon it; nor can the water be kept too long upon it, particularly in winter; and the closer it is fed the better. To improve strong clay soils we must endeavour to the utmost to procure the greatest possible descent from the trench to the trench-drain, which is best done by making the latter as deep as possible, and applying the materials taken out, to raise the trenches. Then with a strong body of water, taking the advantage of the autumnal floods, and keeping the water some time upon them at that season, and as often as convenient during the winter, the greatest improvement on this sort of soils may be made. Warm sand or gravelly soils are the most profitable under the watering system, provided the water can be brought over them at pleasure. In soils of this kind the water must not be kept long on at a time, but often shifted, thoroughly drained, and the land frequently refreshed with it; under which circumstances the profit is immense. A spring feeding, a crop of hay, and two aftermaths, may be obtained in one year; and this, probably where, in a dry summer, scarce grass enough could be found to keep a sheep alive. If the stream be large, almost any kind of land may be watered; and though the expense of a ware over it be great, it will soon be repaid by the additional crop. If the stream be small, the expences will be so in proportion."

With respect to the time during which the water should remain upon the land, no precise rules can be laid down: experience is in this, as in many other practices of husbandry, the safest guide. It may however be proper to observe that, in warm weather, water remaining on the ground will very soon produce a white substance like cream, which is very prejudicial to the grass, and shews that the water has been on the land too long already. If it be permitted to remain a little longer, a thick scum will settle upon the grass, of the consistence of glue, and as tough as leather, which will quite destroy the grass wherever it is suffered to be produced.

Rotation of crops. No branch of husbandry requires more skill and sagacity than the proper change or rotation of crops, so as to keep the ground always in good heart, and yet to draw out of it the greatest possible profit. Some plants rob the soil, others are gentle to it; some bind it, and some loosen it. The nice point is to intermix crops so as to make the greatest profit, consistently with keeping the ground in proper trim; and for this purpose the nature of the plants used in husbandry ought to be accurately examined.

It was formerly mentioned that *culmiferous* plants are those which have a smooth jointed stalk or stem, usually hollow, wrapped about, at each joint, with single narrow sharp-pointed leaves, and having their seed contained in husks: of this sort of plants are wheat, rye, barley, oats, rye-grass. *Leguminous* plants, on the contrary, are very various in their manner of growing, but they bear their fruit in pods, such as pease, beans, vetches, clover, cabbage. Culmiferous plants having small leaves and few in number, must depend mostly on the soil for nourishment, and but very little on the air. During the ripening of the seed they probably draw the whole of their nourishment from the soil; as the leaves by this time, being dry and withered, must have lost their power of drawing food from the air. Now as culmiferous plants are chiefly cultivated for their seed, and are not cut down till that seed be fully ripe,

all such plants may be pronounced to be all robbers of the soil, in a greater or less degree. But such plants, while young, are all leaves, and in that state draw their food chiefly from the air; hence it is, that when cut green for feeding cattle, a culmiferous crop is far from being a robber. A hay crop, accordingly, even where it consists mostly of rye-grass, is not a robber, provided it be cut before the seed is formed, as it ought to be at any rate, if one would have it in perfection: and the fog-gage excluding the frost by covering the ground keeps the roots warm. A leguminous plant, by its broad leaves, draws much of its nourishment from the air. Thus a cabbage, which has very broad leaves, and a multitude of them, owes its growth much more to the air than to the soil. One thing is certain, that a cabbage cut and hung up in a damp place, preserves its verdure longer than other plants. At the same time the seed is that part of a plant which requires the most nourishment, and for that nourishment a culmiferous plant must be wholly indebted to the soil: a leguminous plant, on the contrary, when cut green for food, must be very gentle to the soil. Pease and beans are leguminous; but being cultivated for seed, they seem to occupy a middle station: their seed makes them more severe than other leguminous plants cut green; and their leaves, which grow till reaping, make them less severe than a culmiferous plant left to ripen.

These plants are distinguished also by another remarkable circumstance: all the seeds of a culmiferous plant ripen at the same time. As soon as they begin to form, the plant becomes stationary, its growth is stopt, the leaves wither, the roots cease to push out, and the plant when cut down is blanched and sapless. The seeds of a leguminous plant are formed in succession; flowers and fruit appear at the same time in different parts of the plant, which is accordingly in continual growth, and constantly pushing its roots. Hence the value of bean or pease straw above that of wheat or oats: the latter is withered and dry when the crop is cut; the former is still green and succulent. The difference, therefore, to the soils between a culmiferous and a leguminous crop is very great. The latter growing till it is cut down, keeps the soil in constant motion, and leaves it loose and mellow for the plough. The former gives over growing long before reaping; and the ground, from want of motion, becomes compact and hard. Nor is this all: the dew falling on a culmiferous crop, after the ground begins to harden, rests on the surface, and is sucked up by the sun. Dew that falls on a leguminous plant is shaded from the sun by the broad leaves, and sinks at leisure into the ground. The consequence of all this is, that after a culmiferous crop the ground is not only hard but dry; whereas after a leguminous crop it is not only loose, but soft and unctuous or moist.

Of all culmiferous plants wheat is the most severe on the soil, by the long time it occupies the ground without admitting the plough; and as the grain is heavier than that of barley or oats, it probably requires also more nourishment from the soil than either of those grains. Bulbous-rooted plants are above all useful in moving, dividing, and pulverizing the soil. Potatoe roots grow six, eight, or ten inches under the surface, and by their number and size they separate the particles of the ground far better than can be done by the plough; the consequence of this is, whatever be the natural colour of the soil, it is always black when a potatoe is taken up. The potatoe however must, as a divider of the soil, give way to the carrot and parsnip, which are large roots, piercing often

to the depth of eighteen inches. The turnip by its tap-root divides the soil more than a fibrous rooted plant; but as its bulbous root grows mostly above ground, it divides the soil less than the potatoe, the carrot, or the parsnip. In this respect red clover may be put in the same rank with turnip. Whether potatoes or turnips be the more gentle crop is a puzzling question. The former bears seed, and probably draws more nourishment from the soil than the latter, when cut green. On the other hand, potatoes divide the soil more than turnips, and leave it more loose and friable. It is no less puzzling to determine between cabbage and turnip: the former draws more of its nourishment from the air, the latter leaves the soil more open and free. The result of the whole, however, seems to be this:—that culmiferous plants are all robbers, some more, some less; they, at the same time, bind the soil, some more, some less. Leguminous plants are, in both these respects, different: if any of them rob the soil it is in a very slight degree, and all of them without exception loosen the soil. A culmiferous crop, however, is generally the more profitable; but few soils can long bear the burden of such crops, unless relieved by leguminous crops thrown in between them. These last, on the other hand, without a mixture of culmiferous crops, would soon render the soil too loose for use.

These observations may carry the farmer some length, in directing him in the choice of a proper rotation or succession of crops. Where dung, lime, or other manure can be procured in plenty, to recruit the soil after severe cropping, no succession or rotation is more proper or profitable, in a strong soil, than wheat, pease or beans, barley, oats, fallow. Under this rotation the whole farm may be brought, excepting so far as hay is concerned, But as such a command of manure is rare, it is of more importance to determine what should be the rotation, when no manure can be procured but that raised on the farm itself. Considering that culmiferous crops are the most profitable on rich land, it would be proper to make them more frequent than the other sort. But as few even rich soils could bear such frequent culmiferous crops without suffering, it may be laid down as a general rule that alternate crops, culmiferous and leguminous, should succeed one another by turns. Nor are there many soils that will stand good even with this rotation, however favourable, unless relieved, from time to time, by pasturing a few years. If such extended rotation, including pasturage, be skilfully carried on, crops without end may be obtained, in a tolerably good soil, without any other manure but what is produced on the farm itself.

It is scarcely necessary to mention, being known to every farmer, that clay answers best for wheat, moist clay for beans, loam for barley and pease, light soil for turnip, sandy soil for rye and buck wheat, and that oats thrive better than any other grain in coarse soil. Now, in forming a rotation, it is not sufficient that a culmiferous crop be always succeeded by a leguminous: we must also be attentive that no crop, however proper as a successor, be introduced that is not adapted to the soil. Wheat being a great binder, requires more than any other crop a leguminous one to follow. Potatoes are the greatest openers, but they are improper in a wheat soil; neither will turnip answer, because it requires a light soil. A very loose soil, after a crop of rye, requires rye-grass to bind it, or the tread of cattle in pasturing; but to bind the soil wheat must not be ventured, because it does not thrive well in loose soil.

Where a farmer can procure no manure but what is of his own pro-

duction, many variations and successions of crops may be tried, all of them good, although perhaps not all equally so. The following examples, one in clay, and one in free soil, have been found very successful, both on small farms of ninety acres each. Six acres are inclosed for a kitchen garden, &c. in which is annually a crop of red clover, for summer food to the working cattle. As there are annually twelve acres in hay and twelve in pasture, a single plough with good cattle is sufficient to command the remaining sixty acres.

Rotation on a Clay Soil.

Inclosure.	1st. Year.	2d.	3d.	4th.	5th.	6th.
1	Fallow.	Wheat.	Pease.	Barley.	Hay.	Oats.
2	Wheat.	Pease.	Barley.	Hay.	Oats.	Fallow.
3	Pease.	Barley.	Hay.	Oats.	Fallow.	Wheat.
4	Barley.	Hay.	Oats.	Fallow.	Wheat.	Pease.
5	Hay.	Oats.	Fallow.	Wheat.	Pease.	Barley.
6	Oats.	Fallow.	Wheat.	Pease.	Barley.	Hay.
7	Pasture.	Pasture.	Pasture.	Pasture.	Pasture.	Pasture.

When the rotation is completed, every field will have borne, in its turn, the same succession of crops; and the inclosure No. 7, having been six years in pasture, is ready to be taken up for a course of crops, beginning with oats, and going on as in inclosure No. 6. In this arrangement labour is equally distributed, without hurry or confusion, over the farm: but the chief advantages of this rotation are, that two culmiferous or white-corn crops never come together on the same land; and that by a due mixture of crops, the soil is preserved in good heart without any extraordinary manure. The land is always producing plentiful crops, and neither the hay nor the pasture have time to degenerate. The whole dung of the farm is laid upon the fallow. Every farm that takes a grass crop into the rotation must be inclosed, especially on a clay soil, as nothing is more hurtful to it than poaching.

Rotation on a Free Soil.

Inclosure.	1st. Year.	2d.	3d.	4th.	5th.	6th.
1	Turnips.	Barley.	Hay.	Oats.	Fallow.	Wheat.
2	Barley.	Hay.	Oats.	Fallow.	Wheat.	Turnips.
3	Hay.	Oats.	Fallow.	Wheat.	Turnips.	Barley.
4	Oats.	Fallow.	Wheat	Turnips.	Barley.	Hay.
5	Fallow.	Wheat.	Turnips.	Barley.	Hay.	Oats.
6	Wheat.	Turnips.	Barley.	Hay.	Oats.	Fallow.
7	Pasture.	Pasture.	Pasture.	Pasture.	Pasture.	Pasture.

For the next rotation the inclosure No. 7, is taken up for corn, beginning with oats, and proceeding in the order of No. 4; in place of which No. 3 is laid down for pasture, by sowing pasture-grasses with the last crop in that inclosure, which is barley. This rotation has all the advantages of the former, and the whole dung is employed on the turnip crop.

Drill, or Horse-hoeing Husbandry.

The general principles on which are founded the operations of drill husbandry are the promoting of the growth of plants by horse-hoeing, and the sowing of the seed-corn, both objects of great importance to the farmer. The advantages of repeated tillage before sowing are well known: those of repeated tillage called horse-hoeing after sowing are also very great.

Land sown with wheat, however well it may be cultivated in autumn, sinks in winter; the particles of the soil get nearer to each other, and the weeds rise, so that in spring the land is nearly in the same state as if it had never been ploughed. This however is the season when the wheat should branch and grow with vigour, and consequently when it stands the most in need of ploughing or hoeing, to destroy the weeds, to supply the roots with fresh earth, and by separating anew the particles of the soil to allow the roots to extend and collect food. It is well known that in gardens, plants grow with double strength, after being hoed or transplanted. If plants in arable land could be managed with ease and safety in the same manner, it is natural to expect that their growth would be proportionably promoted; and this experience has shown to be not only practicable, but productive of many advantages. In hoeing wheat, though some of the roots be moved or even broken, the plants receive no injury: for this very circumstance causes them to send out a greater number of roots than before, and consequently to enlarge the space from which they draw nourishment, and so increase their growth. Sickly wheat has often recovered its vigour after a good hoeing, especially when done in weather not very hot or dry. Wheat and the other grains which are sown before winter require hoeing, more than oats, barley, or other grain sown in spring: for if the land has been well ploughed before the spring corn was sown, it has neither time to harden nor to produce weeds, not having been exposed to the snow and rain of winter.

Of sowing. As in the new or drill husbandry plants grow with greater vigour than by the old method, the land should be thinner sown. This is the principle to which objections have chiefly been made, for upon observing the land occupied by a small number of plants, people are apt to look upon all the empty space as lost. But this opinion will soon be removed, when it is considered that in the best land cultivated in the old way, and sown very thick, each seed produces but one or two ears; that in the same land sown thinner, each seed produces two or three ears, and that a single seed sown by itself with room about it, has been known to produce 18 and even 21 ears.

In the common method, as there are many more plants than can find proper nourishment, and as it is impossible to assist them by hoeing, numbers die before they come to maturity, the greatest part remain sickly and drooping, and thus much of the seed sown is lost. In the new method, on the contrary, all the plants have as much food as they require, and as they are, from time to time, assisted by hoeing they become so vigorous as to equal in their production the numerous but feeble plants raised in the common old way.

Of hoeing. The new husbandry is absolutely impracticable in lands

that are not easily ploughed. The attempt to cultivate land according to the new method, without attending to this circumstance that it can be practised in no land that has not already been brought into good tilth by the old method, has gone far to bring descredit on the new husbandry in many quarters. When a field has been well ploughed and harrowed, it is divided into rows at the distance of 30 inches from one another. On the sides of each of these rows, two rows of wheat are sown, six inches distant from each other. By this method there will be an interval of two feet wide between the rows, and every plant will have room enough to extend its roots, and to collect nourishment. These intervals will also be sufficient for allowing the ground to be hoed or tilled, without injuring the plants in the rows.

The first hoeing should be given before the winter set in, to drain away the wet, and prepare the earth to be mellowed by the frosts; which ends will be answered by drawing two small furrows, at a little distance from the rows, and throwing the earth into the middle of the intervals. The second hoeing, to make the plants branch, should be given after the hard frosts are over. The third to strengthen the stalk, should be given when the ears begin to show themselves, and may be very light. The fourth and last hoeing is of the greatest importance, as it enlarges the grain, and makes the ears fill at the extremities. This should be given when the wheat begins to bloom: a furrow is drawn in the middle of the interval, and the earth thrown to the right and left on the feet of the plants. The best season for hoeing is two or three days after rain: light dry soils may be hoed almost at any time; but this is by no means the case with strong clay soils.

By this repeated tillage or hoeing, good crops will be obtained, provided the weather be favourable; but as strong vigorous plants are long before they arrive at maturity, corn raised in the new way is later in ripening than any other, and must therefore be earlier sown.

In order to prepare the intervals between the rows for sowing again, some well-rotted dung may be laid in the deep furrows made in the middle of the intervals; and this dung must be covered with the earth that was before thrown towards the rows of wheat; an operation to be performed immediately after harvest, that there may be time to give the land a slight stirring before the new rows are sown, in the middle of the space between the former rows. Supposing dung to be necessary, which is denied by many, a single thin layer in the bottom of each furrow is enough.

That the practical farmer may have a distinct notion of the nature of the new or drill husbandry, a summary of the operations necessary in it is here subjoined, in a number of separate heads, in the order in which those operations are executed.

1. It is indispensably necessary that the farmer be provided with a drill-plough, and a hoe-plough.

2. The new husbandry may be begun either with the winter or the spring corn.

3. The land must be prepared by four good ploughings, given at different times, from the beginning of April to the middle of September.

4. These ploughings must be done in dry weather, to prevent the earth from kneading.

5. The land must be harrowed in the same manner as if it were sown in the old common way.

6. The rows of wheat must be sown very straight.

7. When the field is not very large a line must be stretched tight across it, by which a rill may be traced with a hoe, for the horse that draws the drill-plough to walk in; and when the rows are sown 50 inches must be left between the rills. When the field is very large, however, stakes at 5 feet distance from each other must be placed at each end. The workman must then trace a small furrow with a plough that has no mould board, for the horse to walk in, that draws the drill, directing himself with his eye by the stakes.

8. The sowing should be finished by the end of September, or the beginning of October.

9. The furrows must be traced the long way of the land, that as little ground as possible may be lost in head-lands.

10. The rows should, if possible, run down the slope of the land, that the water may the easier get off.

11. The seed-wheat must be plunged into a tub of lime-water, and stirred, that the light corn may come up to the surface, and be skimmed off.

12. The seed must be next spread on a floor, and frequently stirred, till it is dry enough to run through the valves of the hopper of the drill.

13. To prevent smut, the seed must be put into a ley of ashes or lime, or of some other preferable ingredients.

14. Good old seed-wheat should be chosen, in preference to new, as it is found by experience not to be so subject to smut.

15. After the hoppers of the drill are filled, the horse must go slowly but uniformly along the furrow traced for his path. Care must be taken that the opening of the hopper be properly suited to the size of the grain, in order that a proper quantity of seed may be sown.

16. As the drill is seldom well managed at first, the field should be examined after the corn has come up, and the deficiencies supplied.

17. Upon wet or strong clay, wheat should not be deposited more than two inches deep, on any account whatever; nor less than two inches deep on dry soils. From two to three inches are sufficient for all spring corn. But the precise depth at which grain should be laid, in different soils, from the lightest sand to the strongest clay, is readily ascertained, by observing at what distance below the surface the secondary or coronal roots are formed in the spring.

18. Stiff lands that retain the wet must be stirred or hoed in October. This should be done by opening a furrow in the middle of the intervals between the rows, and afterwards filling it up by a furrow drawn on each side, which will raise the earth in the middle of the intervals, and leave two small furrows next the rows, for draining off the water, which is very hurtful to wheat in winter.

19. The next stirring must be given about the end of March, with a light plough. In this stirring the furrows made to drain the rows, must be filled up by earth from the middle of the interval.

20. Some time in May, the rows must be evened, which, though troublesome at first, soon becomes easy, as the weeds are soon kept under by tillage.

21. In June, just before the wheat is in bloom, another stirring must be given with the plough. A deep furrow is made in the middle of the intervals, and the earth is thrown upon the sides of the rows.

22. When the wheat is ripe, particular care must be taken in reaping it, to trample as little as possible on the ploughed land.

23. Soon after the wheat is carried off the field, the intervals must be turned up with the plough, to prepare them for the seed. The great furrow in the middle must not only be filled up, but the earth must be raised as much as possible in the middle of the intervals.

24. In September, the land must be again sown with the drill, as before directed.

25. In October the stubble must be turned in, for forming the new intervals; and the same order of management begun and carried on, as in the first year of the husbandry.

Drill husbandry may in general be described as *the practice of the garden carried into the field.* All men must agree, that the practice of the garden is much better than that of the field, only a little more expensive: but if, as is really the case in proper circumstances, this extra expence be much more than repaid by the value of the drilled crops, which of the two kinds of husbandry, the old or the new, should be preferred, cannot be doubtful.

It is proper to remark, that what we call the new or the drill husbandry, although but lately introduced into Britain, is by no means a modern invention in itself. It is now actually used in India, where it has most probably existed, among the industrious cultivators of that country, from a very early period. They use it not only for all sorts of grain, but for the culture of tobacco, cotton, and the plant from which castor-oil is extracted. Besides the drill plough, and the common plough, the Indians use a third having a flat horizontal share, which immediately follows the drill plough when at work. It is set in the earth to the depth of seven or eight inches, and passes under three drills at once. It operates by agitating the earth, so as to make the sides of the drills fall in, and cover the seed, which it does so effectually as scarcely to leave any traces of a drill.

Cultivation of certain Vegetables, properly Articles of Commerce.

The vegetables cultivated chiefly with a view to their uses in commerce and manufacture are various: the principal are *flax* and *hemp*, *rape* or *cole seed*, *hops*, *apples*, *pears*, *&c.*

1. *Flax* is cultivated not only for the purpose of making linen cloth, but also for its seed, from which is extracted an oil of very extensive use in painting, and other operations. The seed-cake remaining after the extraction of the oil by the press, is in some places used as a manure, in others for the fattening of cattle. In Yorkshire, where considerable quantities of flax are raised, the kind chiefly cultivated is the *blea-line*, or the *blue lead coloured flax*, which requires a rich dry soil. A deep fat sandy loam is perhaps the best soil. When sown upon old corn-land the soil is to be well cleaned of weeds, and rendered perfectly friable by summer fallow. Manure is seldom or never set on for a line crop, and a single ploughing is generally enough. The seed time is in May; but the soil should be neither wet nor dry, and the surface ought to be made as fine as that of a garden bed; not a clod the size of an egg should remain unbroken. Two bushels of seed are usually sown on an

acre: the surface after being harrowed is sometimes raked with garden or hay rakes: a light hand roller, used between the final raking and harrowing, would be of great service. The chief requisite in the time of the growth is weeding, which must be performed with the greatest care; and if the ground is not very clean beforehand, the expence of weeding must be great, or if this be neglected, the crop must be greatly injured. The goodness of the crop consists in the plants running up with a single stalk without branches; for wherever the branches set off, there the length of the *line* terminates. These branches are never of any use, for they are unavoidably worked off in the dressing of the flax; and the branches seem to be commonly occasioned by clods on the ground when sown. Flax is injured not by drought only but by frost, and is sometimes attacked, even when got five or six inches high, by a small white slug, which strips off the leaves to the top, and the delicate stalks are often bent to the ground with their weight. In Yorkshire the time of flax-harvest is generally in the latter end of July, or the beginning of August. In general flax is a good crop when it is three feet high, and of the thickness of a crow quill. A fine stalk affords more line and fewer shivers than a thick one; a tall thick crop is therefore desirable: but unless the land be good a thick crop cannot attain a sufficient length. Some consider both flax and hemp to be exhausting crops for the land; others on the contrary esteem them both to be improvers of the soil, if taken off without seeding, an operation of very little use in this country, where foreign seed is commonly employed for sowing.

The quantity of flax and hemp raised in Britain is, compared with the consumption, extremely small: the great supplies are drawn from the northern parts of Europe, particularly from Russia, Poland and Prussia, where those most useful plants are cultivated in the following manner. A black, but not morassy, open gravelly soil is preferred, as flax and hemp become exuberant and coarse on too rich a soil. To ascertain the proper middle strength of soil, crops of corn are previously taken off it. On a vigorous soil wheat is first sown, then rye, barley, oats, and last of all, flax or hemp. Two successive crops of hemp are taken, if the land is immediately dunged: for one crop of flax it is not dunged at all. The land is ploughed in autumn if the weather allow; and if not, in the following spring; it is then harrowed and manured, and again ploughed immediately before sowing. A field that has been laid down in fallow, if only ploughed up, yields a better crop of flax than if it had been manured and cultivated. Flax and hemp are sown from the 25th of May to the 10th of June, and the flax is reaped in the end of August but the hemp not till the end of September. No kind of grain can be sown immediately after a crop of flax without dunging: but after a crop of hemp any grain, and even hemp itself may be sown without manure. Hemp cleans the ground, by suffocating with its broad leaves all sorts of weeds; but flax must be weeded generally twice before it bloom. Flax is pulled when the stalk becomes yellowish, the pods or bolls brown, and the seed hard and full-bodied. For the finer flax the stalk is pulled while still green: but the seed is then sacrificed, and is fit only for crushing to make oil, of which it yields a small quantity. Hemp is also pulled or drawn when the stalk and pods have changed colour. If the flax be very dry when pulled, the seed is immediately stripped off: if it be not, it is allowed to dry on the field. The seed-pods are spread thinly on a floor, where they are turn-

ed twice a day, until so dry that they open of themselves, when they are threshed, and the seed cleaned like any other grain. To obtain the hemp-seed, the hemp itself when drawn, is set on end, against some convenient support: the roots and top-ends are then cut off; the roots are thrown away, but the tops are threshed out and cleaned. Hemp-seed is apt to spoil by remaining any length of time in a moist state.

As soon as the seed has been secured, the flax and hemp are steeped in water, till the flax separate from the rind, and till the harl of the hemp spring from the stalk. In soft water, in warm weather, nine or ten days are sufficient for this purpose. In hard water with cold weather, from fourteen days to three weeks are requisite. Standing is preferred to running water. In the southern provinces of Poland steeping is not practised, on the supposition that it weakens the harl and darkens the colour: but this idea seems to be without foundation. When taken out of the steep, the flax is dried on a grass field, and then gathered up into small stacks; but the hemp, instead of being spread out, is set up against walls till it be dried, and then both are housed. It is generally understood in those countries, that the cultivation of flax and hemp is more profitable than that of any kind of grain.

The management of flax in Ireland, is as follows. A good crop of flax is there expected from any strong clay fit for corn: but an open black loamy soil, enriched by lying long in pasture, is preferable. The ground must be in fine tilth, and as free as possible from weeds. Potatoes usually go before flax, though turnips, beans, or any manured crop, are a good preparation; but the first or second crop after pasture is preferred to any of those. Stubble lands that have been long in tillage, may by preparation bring a crop: but it is apt to fail in such situations, the stalks turning to a reddish colour called *firing*, before it ripen; upon which it must be immediately pulled. Two bushels of seed are used to the English acre, unless for the purpose of a very fine manufacture, when a larger quantity of seed is used, and the flax is pulled very green. The season of sowing is the first fine weather after the middle of March. The most approved culture is in beds six feet broad, covering the seed about an inch and a half deep with earth shovelled out of the furrows; but the most common way is to sow on common ridges, and to harrow in the seed. Before the flax be five inches high it should be carefully weeded by the hand, and if any plants be lodged they are turned over. The produce is usually about L.7 Sterling the English acre. The crop should stand till the lower part of the stalk become yellowish, and the under leaves begin to wither; unless the seed be to be preserved, which is done by *rippling* or drawing the stalks through an iron comb; and the flax may be steeped immediately after it is pulled. Turf or peat bog water answers well: but foul stagnated water stains the flax: too pure a spring is injurious; a reservoir dug in clay is preferred: the flax is dried upon grass, by being spread thin: artificial heat has been recommended, but no good method of doing so has yet been introduced.

In addition to the foregoing information, it may be of service to mention a mode of weeding flax used in Scotland, which consists in turning a flock of sheep at large into the flax field. The sheep will not taste the flax plants, but they carefully search out and devour the weeds.

Rape, or cole seed. This seed as well as the seed of flax or linseed, is cultivated for the making of oil, and it will grow almost in any place,

In the north of England, the farmers pare and burn their pasture lands, and then sow them with rape, after one ploughing; the crop standing for seed, which is ripe in July or the beginning of August. When fully ripe, it is cut with sickles, and laid thin upon the ground to dry; and when in a proper state for threshing out, the neighbours round are invited to lend their assistance; on which account that is always a season of merry-making among the farmers. The threshing is performed on a large cloth spread out in the middle of the field, and the seed is put up in sacks, and carried home. This operation must be done in the field, because the seed would fall out of the pod were it carried to any distance. The straw is burnt for the sake of the ashes, from which an *alkali* is extracted, not much inferior to the best brought from abroad. In Flanders the cole-seed is sown in July, and the young plants are transplanted out in September, by means of a narrow spade pushed into the ground, and moved a little forwards and backwards, to make an opening to receive the plants, placed in it by a boy or girl, who, with the foot, presses the earth close again. When the plantation is done with the plough, the plants are placed at regular distances in the furrow, leaning against one side, and are covered by the earth turned up by the following furrow.

Coriander seed is used in large quantities by the distillers, confectioners, and druggists; and the culture of that plant might be an object for farmers residing near great towns. Ten perches of good sandy loam were sown with coriander seeds, on the 23d of March, several years ago. Three pounds of seed were sufficient; and the whole expence amounted to five shillings and tenpence. The produce was 87 pounds of seed, which at threepence per pound, gave a profit at the rate of L.15. 18. 4. per acre.

Canary seed is cultivated in large quantities in that part of Kent called the isle of Thanet, where it frequently gives twenty bushels to an acre.

Woad is of so much use in dying, and the consumption of it is so great, that the raising of the plant might undoubtedly be an object worthy of the attention of the husbandman, provided he could get it properly manufactured for the dyers, and that he could overcome their prejudices. At present the growth of woad is in a manner confined to the neighbourhood of Keynsham, near Bristol, where the soil is a blackish heavy mould, with a considerable portion of clay, but which works freely. An experiment was made on a hazel sandy loam, at a place in the vicinity, where the plant throve perfectly well; the proprietor being, however, unacquainted with the manner of preparing it for the dyer, the plant ran to seed; shewing, at the same time, that it was very easily cultivated.

Hops. The uses of this plant, as an ingredient in malt liquors, are well known: formerly, however, hops were esteemed to possess qualities so noxious, that the use of them was prohibited by an act of parliament, in the reign of James I. But although this act was never repealed, it seems never to have been much attended to, as the use of hops has been always continued, without any bad effects on the human constitution, and has even been publicly recognised, in becoming the object of taxation. The only question now is, whether or not hops be an article deserving the attention of the husbandman; and the affirmative is, to say the least of it, very doubtful. The culture of hops is in a great measure confined to the southern counties of England: formerly some were raised in Nor-

folk, but that branch of husbandry has long been falling off in that quarter. From long observation it is clear, that hops are, perhaps, the most uncertain and precarious crop on which labour can be bestowed. Some improvements might, however, be introduced in their management, such as that of planting, and rearing them on espaliers like fruit trees. This hint was taken from observing that a plant, which had been blown down, and afterwards shot out horizontally, always produced a greater quantity of blossom than those plants which grew upright. It has also been observed, that hops late picked, produce more abundantly in the following year, than those which are picked early; wherefore, late picking ought to be preferred: but in the beginning of the season the hops appear more beautiful than afterwards, and that is the only reason for early picking.

Cultivation of fruit, for cyder and perry, is a principal branch of the husbandry of Herefordshire and Gloucestershire. Considerable quantities of those liquors, though in a much smaller proportion, are also made in Devonshire.

Nature seems to have produced but one sort of apple and pear, namely, the common crab of the woods and hedges, and the wild pear, which is also not uncommon. The varieties of these fruits are entirely artificial, being produced, not by seed, but by a certain mode of culture. It is, perhaps, impossible to render the varieties of fruit altogether permanent: the time comes when they can no longer be propagated with success. The old fruits which raised the fame of the cyder and perry counties, are either lost or irrecoverably declined. The *red streak* is given up; the famous *stir-apple* is going off; and the *squash-pear,* which has probably furnished England with more *genuine* Champaign wine than ever crossed the sea, can no longer be made to flourish. This decay among fruit trees is also observed in other parts of the kingdom. Others are, however, of opinion, that the degeneracy of fruit in the ancient orchards, proceeds chiefly from not varying the seeds, by introducing those of other and distant countries, as is always done with every kind of grain or vegetables.

In raising new varieties of apples, the following simple process has been found extremely useful. Choose among the native kinds the individuals of the highest flavour, and sow the seeds in a highly enriched seed-bed, on a good loamy soil, which should be double-dug, from 12 to 18 inches, and kept perfectly clean. The surface being raked and levelled fine, the seeds are scattered on the bed, about an inch asunder, and covered half an inch deep with some of the finest mould, previously raked off the bed for the purpose. During summer, the young plants should be kept clear of weeds, and may be taken up for transplantation the ensuing winter, or if not very thick in the bed, they may remain in it till the second winter. The nursery ground ought also to be enriched, and double-dug, to the depth of 14 inches at least, though 18 or 20 will do better. The tap-roots should be taken off, and the longer side-roots shortened; the young trees are then planted in rows, three feet asunder, from 15 to 18 inches distant in the rows. If intended merely for stocks to be grafted, they may remain there till they grow large enough to be planted out; though, in strictness, they ought to be re-transplanted two years before they go to the orchard. From among the seedlings, select the plants of which the wood and leaves have the most apple-like appearance: transplant these into a rich deep soil, in a kindly

situation, letting them remain in this nursery until they begin to bear. With the seeds of the fairest, richest, and best flavoured fruit, repeat this process, and in due time ingraft the wood which produced this fruit on that of the richest, sweetest, and best flavoured apple. Repeating this operation, and transferring the subject under a course of improvement, from one tree and sort to another, as good qualities may require; by this double course of melioration, the desired fruit will at last be obtained.

While fruit trees remain in the nursery, the intervals between them may be occupied by such kitchen stuff as will not crowd or overshadow the plants, keeping the rows always perfectly clean. In pruning them, the leader should be particularly attended to. If they shoot double, the weakest of the two shoots should be taken off; but if the leader be lost, and not easily recoverable, the plant should be cut down to within a hand's breadth of the ground, and a fresh stem trained up. The undermost boughs should be taken off by degrees, going over the plants every winter, but taking care to preserve heads of sufficient size, not to draw up the stems too tall, which would make them feeble in the lower part. In Herefordshire, the stems are trained to the height of six feet; but some skilful cultivators would train them to seven or eight feet. A tall stemmed tree is far less injurious to what grows beneath it than a low-headed tree; and the short stemmed tree is itself the more exposed to accidental injury. The thickness of the stem ought to be in propoportion to its height; wherefore, a tall stock ought to remain longer in the nursery than a low one. The usual size at which they are planted out in Herefordshire, is from four to six inches girt, at three feet high, which size the trees will reach, with proper management, in seven or eight years. In Herefordshire, it is common to have the ground of the orchards in tillage, but in Gloucestershire in grass, on account of the different soils; that of the former county being in general arable, and that of the latter in grass. Trees, however, are very destructive, not only to corn, but to clover and turnips, at the same time that tillage is favourable to fruit trees, especially while young. In grass grounds their growth is comparatively slow, for want of the earth being stirred about them, and by being injured by cattle. When trees begin to bear, cattle should never go near them, not only because these destroy all the fruit within their reach, but on account of the accidents which happen to the cattle themselves, by the young harsh fruit sticking in their throats, and choking them.

The natural enemies of fruit trees are, 1st, a redundancy of wood; for the barren branches not only deprive the bearers of nourishment, but present a greater surface to violent shaking winds, and retain so much damp, and so much prevent the circulation of air, that only the outside of the tree can bear fruit. 2d, The misletoe, in the cyder counties, is very hurtful to the apple-tree; but it may be easily pulled out with hooks in frosty weather.—Sheep are fond of misletoe as well as of ivy. 3d, Moss can be got the better of only by industry in clearing the trees: in Kent there are people who make a profession to do so. 4th, Spring frosts, succeeding suddenly to rain, are heavy enemies to fruit trees;—dry frosts only keep back the blossom for some time. No remedy can be applied in these cases but to keep the trees in a healthy state, and as thin of wood as possible. 5th, Blight is a term applied to fruit trees, without any proper meaning. Two bearing years seldom come together; but it is probably

the exhaustion of the first year that prevents a second crop from being plentiful or good. 6. Insects destroy not only the blossoms and leaves, but also the fruit, especially pears. In some years much mischief is done by wasps:—if a small price were set upon the female wasps, which are easily known, those insects might soon be materially lessened in an orchard. 8. An excess of fruit stints the growth of young trees, and, in general, renders all trees barren in two or three years, while in many cases the branches are broken or strained by the load of fruit. To prevent such excess, it has been recommended to graft in the boughs, and when fully grown to thin the bearing-branches; then endeavouring, like the gardener, to grow fruit every year. Considering fruit trees as a crop of husbandry, the general management seems to be this: plant upon a worn-out, newly broken up sward; keep the soil under a state of arable management, until the trees be well grown; then lay it down to grass, and let it remain in sward until the trees be removed, and their roots be decayed; when it will again require a course of arable management.

Management of the Dairy. On a subject of such extent and variety, the limits of this work will permit only the following general remarks to be given.

To make cows give abundance of milk, and of a good quality, they must at all times have abundance of food. *Grass* is the best food yet known for this purpose, and that kind of grass which springs up of itself, on rich dry soils, is the best of all. If the state of the weather, in point of heat, be such as to allow the cows to graze at ease throughout the day, they should be suffered to range over such pastures at freedom; but if the cows are so much incommoded by the heat as to be hindered from eating through the day, they ought to be taken into cool sheds for shelter, where, after allowing them a proper time to ruminate, that is, to chew the cud, they should be supplied with plenty of green food, fresh cut for the purpose, and given to them by hand frequently, in small quantities, fresh and fresh, to engage them to eat it with pleasure. When the heat of the day is over, and they can remain abroad with ease, they may be again turned into the pasture, where they should be allowed to range with freedom all night, during the mild weather of summer.

Cows, if abundantly fed, should be milked three times a-day, during the whole of the summer season; in the morning early, at noon, and in the evening, just before night-fall. In the choice of persons for milking, great caution should be employed; for, if that operation be not carefully and properly performed, not only the quantity of the produce of the dairy will be greatly diminished, but its quality also will be very much debased. If all the milk be not thoroughly drawn from the cow, that portion of milk which is left in the udder seems to be gradually absorbed, or taken back into her body; and nature will, in that case, produce and give out no more milk than will be sufficient to supply the waste occasioned by the portion taken away, instead of a quantity equal to the whole of what was in the udder before milking. If this lessened quantity be not again thoroughly drawn off, it will occasion a still further diminution of the quantity of milk formed in the cow; and thus, by a perpetual progression from less to less, after some time, no milk at all will be produced. This, we know, is the gradual course followed, when it is intended to let a cow's milk dry up entirely, without doing her hurt: and by ignorance or inattention on this important though simple process of nature, the profits of a dairy, and even the well-being

of the cows themselves, may be most materially impaired. The importance of these remarks will be evident from a consideration of the following facts :---

1. Of the milk drawn from any cow at one time, that which comes off at the first is always thinner, and of a much worse quality, than that which comes away afterwards : and the richness goes on continually increasing to the very last drop that can be drawn off at that time. An intelligent master of a dairy made a number of experiments on this subject, of which the following were the results. Having taken a number of large tea-cups, and weighed them with great exactness, he filled them in succession from the first to the last of one milking of a number of different cows, the last cup being filled with the dregs of the stroakings. In the first place it appeared, that the quantity of cream obtained from the first drawn cup was, in every case, much smaller than that from the last drawn cup ; and the quantities from the intermediate cups increased regularly as they were later and later in being filled from the cows. So great was the difference between the first and the last cup, from some cows, that the last contained *sixteen* times the quantity of cream produced from the first cup. In no cow was this difference below *eight to one ;* so that upon an average of a number of cows the cup-full of the dregs of the stroakings afforded *twelve* times the quantity of cream produced by the cup filled with the first of the milking. Again, the difference in the quality of the cream obtained from the first and last cups was still much greater than the difference of the quantity. In the first drawn cup the cream was a thin tough film or skin, *thinner* and *whiter* than writing paper ; in the last drawn cup the cream was of a *thick* buttery consistence, and of a glowing richness of colour, which no other kind of cream ever possesses. In the last place, the difference in the quality of the milk remaining in the cups, after the cream was separated, was still greater than either, in respect to the quantity or the quality of the cream. The milk in the first cup was a thin bluish liquid, as if a very large proportion of water had been mixed with ordinary milk : but that in the last drawn cup was of a thick consistence, and a yellow colour, more resembling cream than milk, in both taste and appearance. From these accurate and most important experiments it appears, that the person who, by bad milking of his cows, loses but *half a pint* of the last of the milk, loses in fact about as much cream as would be afforded by *six or eight pints* of milk at the beginning, and loses besides, precisely that portion of the cream which alone can give the highest richness and flavour to his butter.

2. If milk be put into a dish, and allowed to stand till it cream, that portion of the cream which first rises is richer in quality, and more in quantity than what rises in an equal time, next afterwards ; and so on the cream decreasing in quantity, and declining in quality, in equal times from the first to the last. Whether or not a greater quantity of cream may be taken from a given quantity of milk, by skimming it at different times, or by leaving it all on to the last, is a point not yet well ascertained.

3. Thick milk always throws up a smaller proportion of cream than thinner milk : but then the cream is of a richer quality. If water be added to thick milk, it will throw up a considerably greater quantity of cream than the milk alone would have done ; but the quality is at the same time greatly lowered.

4. Milk put into a bucket or pail, and carried to a considerable distance, so as to be much agitated, and in part cooled, before it be put into the milk pans to settle for cream, never throws up so much nor so rich cream as if the same milk had been put into the creaming-pans, directly after it was milked.

From the foregoing well-established facts, the following conclusions may be drawn:

1. It is of importance that the cows should be milked as near as possible to the dairy, to prevent the necessity of carrying and cooling the milk, before it be put into the creaming-pans: and as cows are much hurt by far driving, it must be a great advantage in a dairy farm, to have the principal grass fields as near the dairy or home-stead as possible.

2. The practice of putting the milk of all the cows of a large dairy into one vessel, as it is milked, there to remain till the whole milking is finished, before any part of it is put into the pans, seems to be highly injudicious: not only on account of the loss sustained by agitation and cooling, but more especially because it prevents the dairy master from distinguishing the milk of the good cows from that of the bad cows, so as to keep them separate if necessary. He may thus have the whole of his dairy debased by the milk of one bad cow, and this for years together, without his being able to account for it.

3. If it be intended to make butter of a very fine quality, it will be proper in all cases to keep the milk that is first drawn separate from that which comes last: for if this be not done, the quality of the butter will certainly be much lowered, at the same time that the small additional quantity obtained from the first milk will not in price make up for the loss sustained in point of goodness. Examples of this separation of the first from the last milk at a milking, occur in some mountainous and pasture countries, particularly in the Highlands of Scotland. As the rearing of calves is there a principal object with the farmer, every cow is allowed to suckle her own calf, with the first part of her milk, the remainder only being reserved for the dairy. In order to give the calf its portion regularly, it is separated from the cow, and kept in an inclosure containing all the calves belonging to the same farm. At regular times the cows are brought to the door of the inclosure, where the calves are sure to meet them. Each calf is then separately let out, and runs directly to its mother, where it sucks till the dairy-maid judge it to have enough. Boys then drive back the calf with switches, (but never beat, drag or force it,) while the mother is kept behind, by simply shackling her hind legs; and the dairy-maid milks off what was left by the calf: this is done till all the cows that have calves are milked. The quantity of butter obtained by this management, it is true, is comparatively small: but it produces, in conjunction with the sweet herbage where the cows feed, the richest marrowy butter that can be desired.

4. If the quality rather than the quantity of the butter by the chief object, it will be necessary not only to separate the first from the last drawn milk, but also to take nothing but the cream that is first separated from the best milk; because it is this first rising cream alone that is of the best quality. The remainder of the milk, which will be still sweet, may be either employed in making sweet-milk cheese, or allowed to stand, to throw up cream for making butter of an inferior quality.

5. It follows that butter of the very best possible quality can be obtained only from a dairy of considerable extent; for it is only from the

great quantity of milk given by a great number of cows that as much of the prime cream can be collected as will render its manufacture separately into butter worthy of attention.

6. From what has been said we are naturally led to draw another conclusion, very different from the opinion commonly entertained on this subject, namely that it is probable that the very best butter might be made, with economical management, in those dairies only where the making of cheese is the principal object of the farmer. The reasons of this conclusion are obvious; for if only a small quantity of milk be set apart for butter, all the rest may be made into cheese, while it is yet warm from the cow, and perfectly sweet; and if only that portion of cream which rises during the first three or four hours after milking is to be reserved for butter, the rich milk which is left, after that cream is separated, being still perfectly sweet, may be converted into cheese, with as great advantage nearly as the newly-milked milk itself.

Butter, though used at present as food in most countries of Europe, was but very imperfectly known to the ancients. In our translation of the Hebrew Scriptures in the Old Testament, mention is often made of *butter* at very early periods of the history of the world: but the greatest masters of biblical criticism unanimously agree that the word so translated signifies milk, or rather the *cream* of milk, and can not possibly mean what we call *butter*. The original Hebrew word signifies something liquid, which was used for washing the feet of the wealthy as a luxury, which was also drank, and which had sometimes the power of causing inebriation: and it is known that in Arabia, and other eastern nations, the milk of mares may be so prepared as to produce that effect.

The oldest mention of real butter is in the account, given by the Greek historian Herodotus, who flourished four hundred years before the Christian era, of the Scythians: he says "these people pour the milk of their mares into wooden vessels, cause it to be violently stirred or shaken by their blind slaves, and separate the part which rises up to the surface, as they consider it to be more delicious and valuable than what remains below."

The effects of turnips and cabbages on milk and butter, may be remedied in the following very simple way: it is thus described by an eminent gentleman-farmer of Shropshire. "I find by experience," says he, "that *a small bit of saltpetre*, powdered, and put into the milk-pan, with the new milk, does effectually prevent the cream and butter from being tainted, *although the cows be fed on the refuse leaves of cabbages and turnips.* In the beginning of this last winter, my men were very careful in not giving to the cows any outside or decayed leaves of the cabbages and turnips; yet the cream and butter were sadly tainted; but as soon as the dairy-maid used the saltpetre, all the taint was done away; and afterwards no care was taken in feeding the cows, for they had cabbages and turnips in all states. Our milk-pans hold about nine pints of milk."

Butter is the fat, oily, and inflammable part of milk: it is naturally distributed through all the substance of the milk, in very small particles, interspersed between the caseous or cheesy, and the serous or watery parts, among which it is suspended by a slight adhesion, but not dissolved. When butter is in the state of cream, its properly oily parts are not yet sufficiently united together, to form an uniform mass; they are still separated in some measure by a pretty large quantity of serous, and

caseous particles. The butter is completely formed by pressing out these other particles, by means of continued percussion, or beating the cream with some hard substance; and this is the nature and effect of *churning*.

Cheese, the other grand object of the dairy, is the curd of milk, precipitated or separated from the serous or watery particles called whey, by means of an acid. Cheese differs in quality, according as it is made from new or skimmed milk, from the curd which separates of itself upon standing, or from that which is more speedily produced by the addition of runnet. Cream also affords a kind of cheese, but quite fat and buttery, which does not keep long. When chemically examined, cheese appears to partake much more of an animal nature than butter, or the milk from which it was made. As a food, physicians condemn the use of cheese in great quantities: when new, it is difficult of digestion; and when old, it becomes acrid and hot; and experiment has shewn, that it is of a septic nature, that is, that it has a tendency to promote putrefaction. It is a common opinion, that old cheese digests every thing in the stomach, but remains undigested itself: the first part of the assertion is certainly true; but the last part is most probably false. *Gloucester cheese* is made from new, or as it is called in that and the adjoining counties, *covered milk*: an inferior sort is made from what is called *half-covered milk*: though, when any of these last cheeses turn out to be good, many people are deceived, and purchase them for the best covered-milk cheese: but farmers who are honest, and set a value on the reputation of their dairies, as well as on their own, have the cheeses stamped with a piece of wood, in the shape of a heart, to distinguish them. *Chedder cheese* is in high esteem; but its goodness is chiefly owing to the land on which the cows feed, for the method of making is the same with that pursued in other parts of Somersetshire.

Cheshire cheese is in great reputation; yet no people take less pains with their runnet than the Cheshire farmers. Their cheeses, however, are so large, as often to exceed one hundred pounds weight; to which may be attributed their excellence, joined to the age they are kept, the richness of the land, and above all, to the keeping of such a number of cows as to make such a cheese at once, without adding a second meal's milk. It is true that the curd is salted, and the cheeses are kept in a damp place, where they are carefully turned every day.

Stilton cheeses are made in round or square vats, and weigh from six to twelve pounds each. Immediately after they are made, it is necessary to put them into boxes, made exactly to fit them; for, being extremely rich, they would, without that precaution, swell out, and burst. They should be continually turned every day, in the boxes, and must be kept two years before they are properly mellowed for sale. Some farmers make these cheeses in a net, so that they look when made not unlike an acorn; but these are never so good as the others, having a thicker coat, and wanting that rich flavour and mellowness, which renders them so agreeable to the palate. The making of these cheeses is by no means confined to Stilton and its vicinity; for many farmers in Huntingdonshire (not forgetting Rutland and Northamptonshire), make a similar sort, which they sell for the same price; and all pass under the name of *Stilton cheeses*.

The Stilton farmers makes a cheese every morning; and to this meal of new milk they add the cream taken from that which was milked the

night before. This practice, and the age of their cheeses, have been considered as the only cause of the excellence of the cheese; for, from the nicest observation, it does not appear that the land is, in any respect, superior to that of other counties, where no such cheese is made.

Parmesan cheese. No country certainly produces so much, and so excellent cheese, as England. In different parts of the continent, however, cheese is made, and in considerable quantities, deservedly enjoying a high reputation. Of such cheese, the most celebrated is the Parmesan, so called, because in former times, chiefly made in the environs of *Parma* and *Placentia,* on the south side of the river *Po,* in the heart of *Lombardy,* in the north of Italy. For many years past, however, this cheese is principally supplied by the rich pastures on the north side of the *Po,* extending from *Placentia,* by *Lodi,* to *Milan.* That tract of the country is a fine level plain, naturally well watered by rivers and rivulets, and artificially intersected and crossed in all directions by canals of irrigation in the most advantageous manner. Of the manner of watering these pastures, and of manufacturing the cheese, still known by the name of Parmesan, although now chiefly produced near Lodi, the following accurate account is given by a very competent judge, the celebrated agriculturist, *Arthur Young,* collected during his travels on the continent in the years 1787, 1788, and 1789.

"The practice of irrigation, or of watering lands," says Mr. Young, "is of unknown antiquity in Lombardy. Of all the exertions I have any where seen, in irrigation, they are by far the greatest between Milan and Lodi. The canals are not only more numerous, more incessant, and without interruption, but are conducted with the most attention, care, and expence. There is, for the most of the way, one canal on each side of the road; and sometimes two cross canals are thrown over these on arches, and pass in trunks of brick or stone under the road. A very considerable one, after passing for several miles by the side of the highway, sinks under it, and also under two other canals, carried in stone troughs eight feet wide, and at the same time under a smaller, that is conducted in wood. The variety of directions in which the water is carried, the ease with which it flows in contrary directions, the obstacles which are overcome, are all objects of admiration. The expence thus employed, in the twenty miles from Milan to Lodi, is immense. There is but little rice, and some arable, which does not seem under the best management; but the grass and clover are rich and luxuriant." [Here Mr. Young might have added, that besides grass and clover, these pastures abound in a variety of other natural plants, which give a peculiar flavour and richness to the milk.] "There are here great herds of cows, to which all this country ought to be applied. I cannot but esteem the 20 miles as affording one of the most curious and valuable prospects in the power of a farmer to view. We have some undertakings in England that are meritorious: but they sink to nothing in comparison with these great and truly noble works. This is one of the rides which I wish those to take who think that every thing is to be seen in England.

"The method of making the cheese, known in England by the name of Parmesan, was an object I wished to understand as well as possible. The idea is, that all depends on soil, climate, and irrigation; and the boasted account, that the kings of Naples and Spain, in order to make similar cheese in their territories, at least for their own tables, had procured men of skill from the Milanese for this purpose;—all this contributes to

give a readiness every where in answering questions, as they are all every where very well persuaded, that such cheese can be made no where else.

"In order that I might view the process to advantage, a scientific friend in Milan conducted me to a noted dairy belonging to the family of *Leti.* It is, in the first place, necessary to observe, that the cheeses are made entirely of *skimmed milk,* that of the preceding evening mixed with the morning's milk: the former had stood sixteen or seventeen hours; the latter about six hours. The runnet is formed into balls, and dissolved in the hand in the milk: the preparation is made a secret of; but it is generally known, that the stomach of the calf is dressed with spices and salt. The runnet was put to the milk at twelve o'clock, not in a tub, but in the cauldron or boiler turned from off the fire-place at ten o'clock. The heat was 82° of Fahrenheit, the atmosphere being at the same time 70° of Fahrenheit. In summer, the whole operation is finished by eight in the morning, as the heat of the weather sours the milk in the middle of the day. At one o'clock, the manager of the dairy examined the coagulation, and finding it complete, he ordered his deputy to work it, which he did with a stick armed with cross wires; an operation to serve instead of cutting and breaking the curd, as is done in England, free from the whey. When he has reduced it to such a firmness of *grain* as satisfies the manager, it is left to subside, till the curd being quite sunk, the whey is nearly clear on the surface. Then the cauldron which contains it is turned back again over the fire-hearth, and a quick fire made, to give it the scald rapidly. A small quantity of finely powdered saffron is added, the deputy stirring it all the time with a wired machine, to keep it from burning. The manager examined it, from time to time, between his fingers and thumb, to mark the moment when the right degree of solidity and firmness of grain is attained. The heat was 124½° of Fahrenheit; but it is often 131°. When the manager finds it well granulated by the scalding, he orders his deputy to turn it off the fire; and as soon as a certain degree of subsidence has taken place, empties about three-fourths of the whey, in order the better to command the curd. He then pours three or four gallons of cold water round the bottom of the cauldron, to cool it enough for handling the curd. Then he bends himself into the vessel, in a formidable manner, to view it, resting his feet against the tub of whey, and with his hands loosens the curd at the bottom, and works it into one mass, that it may lie conveniently for him to slide the cloth under it, which he does with much dexterity, so as to inclose the whole curd. To enable him the easier, he returns the whey into the cauldron, which in some degree floats up the curd, which, when taken out, rests for a quarter of an hour or so in a tub to drain. The cheese-vat, in the mean time, is prepared, in a broad hoop of willow, with a cord round to tighten it; and it widens or contracts at pleasure, according to the size of the cheese. Into this vat the curd is fixed, and the cloth is folded over it, and tucked in around. This is placed on a table, slightly inclining, to carry off the whey that drains from the cheese. A round plank, three inches thick, shod with iron, like the block-wheel of a barrow, is laid on the cheese, and a stone, about thrice the size of a man's head, is laid on that, which is all the press used; and there ends the operation. The cheese of the preceding day was in a hoop, without any cloth, and many others were salting, in different hoops, for 30 or 40 days, according to

the season; 30 in summer, and 40 in winter. When done, the cheeses are scraped clean, and then rubbed, and turned in the magazine every day, and rubbed with a little linseed oil on the coats, to preserve them from insects of all sorts. They are never sold till six months old.

"When this business is finished, the morning's butter-milk is added to the whey, and heated, and a stronger acid or runnet used, to make whey-cheese. These cheeses, which are small, are kept in wooden cases, in the smoke of the chimney."

Of the manufacture of Parmesan cheese, another account, by *Mr. Pryce*, will be found in the 7th vol. of the papers of the Bath Agricultural Society.

Before concluding these general observations on the nature and practice of the first and most important of the arts, *agriculture*, it will gratify many practical readers to be presented wish a short statement of the principles on which the system of cultivation now practised in the northern portion of the island is founded, and by which it has acquired its present celebrity. In the course of last year appeared from the press a *General Report of the Agricultural state of Scotland*, for the consideration of the British board of agriculture, by the president, the Right Hon. *Sir John Sinclair, bart.* This report it is impossible to peruse without experiencing the highest satisfaction; for the greater part of it is written by plain practical farmers, or other persons personally concerned in husbandry; a most valuable class of men, whom, it was usual, down even to no remote period, to reproach for ignorance, and obstinate adherence to old and unreasonable customs. The cultivators of almost every part of Europe have long continued stationary, neither inventing nor adopting improvements of any kind; forming almost the lowest order in society, and still, in some parts of the continent, sunk in a state of hopeless slavery. In this favoured island, on the contrary, farmers have been roused, and have emerged from sloth and ignorance; and they, consequently, now share largely in the general improvement, to which their own knowledge, industry, and spirit, have greatly contributed. In the report, the different courses of management, their fitness for the varieties of soil and climate, and the manner in which the several operations are conducted with the greatest saving of labour and capital, are precisely described by persons who wrote from their own experience. The best proof of the excellency of the husbandry now adopted in Scotland, is the amount of the surplus produce, obtained from a soil seldom naturally very rich, and under a climate rather unkindly. This is shown by the revenue of the landholder, which is considerably greater than what is drawn from other land under circumstances much more favourable. This revenue, too, is paid, not from the savings of extreme parsimony, but from the liberal profits of money judiciously laid out in cultivation. While this revenue had advanced at a rate much higher than the price of the produce of land, the profits of the farmer, and the wages of the labourer, have been proportionally augmented. To support all these increased charges, the marketable produce, for general consumption, has been greatly increased.

In all systems of rural economy, the most important points are, first, such as relate to means of preserving and increasing the fertility of the soil, and of drawing from it the most valuable products; and next, the

arrangements which have for their object, to obtain these products with the greatest possible saving of capital and labour. It is not enough that our fields give large crops, without impairing the vigor of the soil; the neat profits may be still inconsiderable; or the whole may be consumed in producing the crop. In the present state of our country, this is a matter of the utmost importance, when the greater part of the people are otherwise employed than in the cultivation of the soil.

The circumstances which have principally contributed to the great and rapid progress of the art of husbandry in Scotland, are the following. The introduction of turnips and clover, has, in a few years, effected an improvement in almost every branch of husbandry, much greater than will easily be believed by those who look only to the value of these crops in the market. By their means, inferior soils, which it was impossible to cultivate with profit under the old system of successive corn-crops, have been rendered productive. Even on land of a better quality, the crops which succeed those, yield double the former produce; so that the whole turnips and clover may be said to be clear gain. Fallow has been banished by turnips from dry soils; and where land is laid down for pasture, one acre of clover and rye-grass will fatten more stock than could formerly exist on ten acres of foul natural growth. The vast addition to both the quantity and the quality of manure, by the consumption of green clover and turnips, is so powerful a recommendation, that in many quarters turnips are now raised for this very purpose alone, on soils not naturally suited to them. Both clover and turnips were cultivated in England above 150 years ago; the latter, however, only in gardens, although their value, in feeding cattle and sheep, was then not unknown; and it was not till the early part of the last century that they were sown in the open field. To the celebrated *Tull* England is indebted for the most approved mode of raising turnips; although we have now reduced his ridges of 6 feet to others of 27 or 30 inches. The reasons he gives for sowing on narrow ridgelets are so just, and so universally felt to be so in Scotland, that it is surprising he should have made so few converts, even at this day, among his countrymen in the southern parts of the island. Even round the metropolis itself, broadcast is almost the only mode employed to raise so valuable and useful a root. The most common application of turnips in the north, was at first to fatten cattle; but on light soils, the full benefit of the crop was not obtained until the greater part was consumed by sheep on the ground. Turnips raised on clay soils, are those still carried to the fold-yard, for the purpose of converting the straw into manure; and on dry loams, they are usually divided betwen the sheep and the fold-yards, by drawing off and leaving ridgelets alternately. The poorest sandy soils yield good crops of corn after turnips consumed by sheep on the ground, being consolidated and enriched at the same time. At first, almost the whole crop of clover and rye-grass was reserved for hay: but this was soon found to be an unprofitable plan upon dry soils, which are now mostly pastured the very first year. On loams and clays, a considerable portion of the crop is cut green for horses and cows, and, in some instances, for rearing and fattening cattle. This practice, which is called *soiling*, deserves to be more generally adopted, both for economy, and for increasing and enriching the dunghill; it has been employed on a large scale, and with great success, by the patriotic *Mr. Curwen*, of Workington Hall, in Cumberland. Whatever may have been the

influence of potatoes upon the population, it is impossible to ascribe to them any great efficacy in the improvement of agriculture in general. They were first cultivated in the open fields in Scotland in 1739, in the county of Stirling. In the western counties where there are many small farms, they are raised to a great extent; but, on the east coast, where modern husbandry has made the greatest progress, they do not enter largely into any rotation of crops, excepting near great towns. The manure they require, and their great bulk and weight, in proportion to their value, which do not allow them to be carried to a distance, are serious objections to their extended culture. Even their employment in feeding horses and cattle is now much diminished, since the introduction of yellow and Swedish turnips. Potatoes cannot be substituted like turnips for summer fallow, even on dry soils; and on strong clays they do not prosper: for such soils beans are preferred for a rotation crop, which when drilled and hoed, supersede the necessity of fallowing oftener than once in a rotation of 6 or 8 years.

Among the varieties of corn recently introduced into Scotland, the most valuable is what is called the *potatoe-oat*. It is said to have been discovered growing in a field of wheat in Cumberland, in 1788; and from the produce of a single grain have been derived those large and productive crops now to be found throughout all the northern counties of Britain. Scarcely any other variety of oats is cultivated upon low and fertile soils in Scotland; for the produce in both corn and meal is greater on such land, than that of any other kind of oats. One great advantage of the potatoe-oat is, that it may be sown in spring on ground where the autumn wheats have partly failed. The old practice of taking two corn crops in succession from the same field is now abolished, by the culture of turnips, clover, and drilled beans; one of which, or of potatoes, or peas, or a fallow, is universally interposed between every two culmiferous crops. The most common rotation of crops, on the best dry soils, lasts for 4 years, viz. 1. wheat or oats from grass, 2. turnips, 3. wheat, barley, or oats, 4. clover, and rye-grass; one half of the farm being under green crops, and the other under white. But on soils of flinty sand, it is necessary to keep the clover land for some years in pasture, unless more manure can be given to it than arises from its own produce. On strong clays the rotations are more varied. On the best soils, wheat and beans have been taken alternately for a number of years: but the most frequent courses are those of 4 and 6 years in this order, viz. 1. fallow, 2. wheat, 3. clover and rye-grass, 4. oats or barley; or in this way, 1. fallow, 2. wheat, 3. clover and rye-grass, 4. oats or barley, 5. beans, 6. wheat. Sometimes the clover and rye-grass are put off to the 5th year, in this order, fallow, wheat, beans, barley or oats, clover, oats; but by this mode the land is neither so clean, nor so finely pulverized as it should be for clover. On clayey soils, the most judicious farmers consider a complete fallow as the foundation of every profitable rotation: in the light soils of the southern counties of England, fallows may be less necessary; but sufficient trials have not yet been made, to enable the husbandman to make up his mind in general on the much disputed point of the utility of fallows. It is by this regular and successive change of white and green crops, this skilful alternation of tillage and pasture, that the husbandry of the north has acquired its reputation.

On the subject of manuring it is to be observed, that the crops are

now cut very low; the straw of the white corns is chiefly used to absorb the excrementitious matters of the domestic animals; the juices of the dunghills are carefully preserved from waste; the dunghill itself being greatly augmented, and enriched by the consumption of green clover and turnips, and made to undergo a greater or less degree of fermentation and putrefaction, according to the soils and crops for which it is intended. Dung is never laid on foul land, and but very rarely on pasture or hay ground, as we see done in the environs of London: it is distributed carefully over a third or a fourth part of the land in tillage, and over the whole in succession, at the time when the soil is in a state to receive the greatest benefit from its operation. For a drilled crop of turnip it is indispensable that the manure be well rotted, that it may quickly hasten the growth of a plant which, in its infancy, is exposed to many deadly enemies. Potatoes will rise abundantly from fresh unfermented manure; and for clay soils, whether in fallow preparing for autumn wheat, or for beans, as the manure has a long time to decompose in the ground, less previous putrefaction is necessary than for turnips. In the best cultivated counties in Scotland, a material improvement has taken place in the use of lime, being now generally laid on finely pulverized land while under fallow, or immediately before it be sown with turnips. Sometimes lime is laid in spring on land intended for pasture, and harrowed in with gress-seeds, instead of being covered by the plough. By this management prodigious improvement has been produced on hill-pastures. But in whatever way this powerful stimulant is applied, great care is now taken not to exhaust the soil by a succession of white crops.

The plough now introduced into universal use in the north, has its name from the inventor *James Small,* who produced it in 1763. Before that introduction, ploughs were worked with 4 oxen and 2 horses, even in the best quarters: but by his improvements the moving power required was reduced two-fifths, while the work is executed by his plough with much greater accuracy, in regard to the depth and breadth of the furrow-slice, and the angle at which it should rest, than by the old ploughs: some of Small's ploughs made wholly of iron, have lately been found very useful. Ploughs drawn by two horses only, and even by one, were well known in England 170 years ago; and the *Rotheram* plough was known by patent in 1720: yet in many of the southern counties 3, 4, and sometimes 5 horses are still yoked to a machine clumsy and unmanageable, which neither goes over so much ground in a given time, nor performs the work so well as the 2 horse plough of the north part of the island. The expence of ploughing with a 4 horse team, attended by a driver besides the ploughman; even should the horses do all other sorts of work in proportion to their number, cannot be so little as 50 per cent. more than the expence of ploughing with 2 horses. The yearly charge of the small plough in Scotland is about L.120 on an average; and as 60 acres may be cultivated by it, in the rotation of crops, the yearly expence is L.2 per acre: when 4 horses are employed it cannot be less than L.3, and probably a good deal more. By this practice therefore the rent must be diminshed L.1 per acre, and the farmer must lose the profit on so much capital wastefully employed. But this is not all; every well-fed horse consumes the produce of 4 acres of middling land; so that 8 acres, which under good manage-

ment would yield food for at least half as many human beings, are thus wantonly sacrificed to inexcusable prejudice and perversity.

It is not here that the reader will expect an enquiry into the relative utility and value of oxen and horses in the labours of husbandry: it is however a certain fact, that in Scotland, with a very few exceptions, oxen have been laid aside, in exact proportion to the progress of modern agriculture. As on a point of this sort the authority of scientific experience must have great weight, it is to be remarked, that the French (who during the long continued disorders with which their country has been visited, have used every effort, and most successfully, both in theory and in practice, to improve every branch of their cultivation) seem to think as meanly of ox teams as the farmers of Scotland. In a complete treatise on husbandry, published in 1809, by the agricultural department of the *Institute of France,* it is expressly stated that all labour in the best cultivated districts, and upon a large scale, is performed by horses instead of oxen. This preference is said to proceed, not from a blind attachment to old custom, but from accurate and experimental observation, and an impartial comparison of the advantages and disadvantages accruing from the employment of those two kinds of animals.

The *threshing-mill* has also had a powerful effect not only in diminishing the charges, but in augmenting the marketable produce of the land. This most useful machine was brought to its perfection about 1786; and is now employed in Scotland on almost every farm of 2 or more ploughs; being wrought by water, wind, or animal power; and in some instances even by steam. The saving of labour by this machine, particularly when driven by water, is so great, that every kind of grain is thrashed and dressed for market at the expence of the dressing alone when the flail is employed. The grain is also by this mill much more perfectly separated from the straw than it ever can be done by hand-labour. The expedition with which the grain is prepared is likewise of great importance. When thrashed by the flail corn usually lies several days, not to say weeks, on a damp floor before it be cleaned, exposed to vermin and pilfering; whereas by a good mill, a large quantity may be thrashed, completely dressed, and secured in the granary in a few hours, and under the owner's eye. Much corn too may be preserved in an unfavourable harvest, when speedily thrashed, which would certainly be spoiled in the field or in the stack. A threshing-mill of great power is an expensive article; but when worked by water it saves at least 5 shillings on every acre of corn, even on farms of a small size: but much more on large farms. If we take into account all its other advantages, especially the additional grain obtained from the straw, its value will not be over-rated when it is taken at 10 shillings per acre.

It is remarkable that in Scotland, as husbandry has been studied and improved, waggons have constantly been laid aside, and 2 horse carts have been introduced; thereby producing a great saving in animal labour. Fanners or winnowing machines were brought from Holland, a century ago, and are now universally used. The skilful position, arrangement, and construction of farm-buildings and fences, have also an effect similar to that of machinery in abridging labour: the advantages of a central position alone of the buildings have been estimated at from one to two hundred pounds yearly on extensive farms.

The intermixture of property and possession called *run-rig*, and *run-dale*, commons, and tithes, have long been almost unknown in Scotland; as also poor-rates, excepting in a few places where a *voluntary* assessment has been formed, quite inconsiderable in its amount, and borne equally by the land-holder and the land-occupier.

The agriculture of Scotland has received great encouragement from the universal practice of holding lands on leases for a considerable term of years, usually one, two, or more terms of 19 years each. A tenant at will is there now almost unknown; and it cannot be denied, that no confidence, however well founded, in the character of a landlord, however excellent, either can or ought to stand in the place of a good and valid lease. In these leases, one or two clauses secure the interest of the landlord, without, in the smallest degree, restraining the just freedom of the tenant; no particular course of management being prescribed until towards the close of the term, when the interest of both parties, so far united, begin to be different. The principal covenants are, that the tenant shall not take two corn crops in succession; and that, at the expiration of the term, he shall leave to his successor a certain proportion of the farm for fallow, or fallow crops, and under cultivated herbage. Straw is never allowed to be sold, excepting near large towns, where manure can be procured in return. When the British farmer shall be set free from the degrading right exercised by the landlord, of destroying his fences and winter crops in pursuit of game, on fields, which, for other purposes, the landlord cannot enter without permission, the connection between the proprietor and the occupier of land in Scotland, will be of the most liberal and encouraging sort, and assume a character as purely commercial and equable as the nature of the concern can admit.

On the subject of the proper general size of farms, much has been written for a number of years past; but both sides seem to have failed in establishing their point chiefly from taking too confined a view of the matter. From the experience of Scotland, it has been found, that when new land is to be brought into culture, or old, but mismanaged land, is to be recovered, large farms alone have been successful. It is only on such farms, secured by a long certain lease, that a man of the necessary capital will bestow his money and his care. For the first three or four or more years, he expects no profit; but he is able to do without it. By the remainder of his lease, however, he is amply indemnified; and on its expiration, the landlord is at no loss to find other persons, of small capital, ready to take a portion of the improved land; by which means, his rent-roll is increased beyond what any great cultivator would give him for the whole. After a certain progress has been made in the spread of knowledge and capital, the enlargement of farms seems to stand still; and at a certain stage beyond that point, they are usually seen to diminish.

As far as the public are concerned, it does not appear that their interests can be affected by the size of farms, provided land be let for what it will bring in a fair open market. It is the interest of the landlord to draw the utmost possible revenue from his property, taking care always to deal with a substantial tenant; and to encourage a free competition on the part of farmers, is the best method to attain his purpose. Again, it is the interest of the tenant, in order to pay his rent, to raise the greatest possible quantity of the most requisite products. And

lastly, it is the interest of the public at large, that the market be fully supplied with those products, not for a few months after harvest only, but regularly throughout the year.

The principal objections to large farms are, that they depopulate a country; which is certainly true, when applied to store-farms, in hilly districts,, where employment is found for a few people only. But it is as certainly false, when applied to tillage farms; on which it has been ascertained, by actual enumeration, that many more hands have been employed since farms were enlarged. Another objection is, that great farmers frequently keep back their corn from market, until they obtain a monopoly price, especially in seasons of scarcity. This notion is now, however, generally exploded. On the other hand, it is evident, that some recent and most valuable mechanical inventions would never have come into general use, had there been no farms of more than 100 or 150 acres;—that no great improvement could have taken place in our live-stock;—that there could have been no system of arrangement, by which every different quality of soil is made to produce those crops, and to feed those peculiar animals for which it is best calculated;—that it would have been next to impossible to combine tillage and pasturage on the same farm, which so powerfully sustain and augment the fertility of the soil;—that the surplus produce, for the supply of towns, would have been inconsiderable at all times; and, from the general exigencies of the small tenants, brought to market in too great abundance in the early part of the season, instead of apportioning it over the whole year;—that, in bad years there would have been no surplus at all;—and that, in short, as no person of capital and enterprise would ever have entered into the profession of a practical farmer, our extensive moors, heaths, and mosses, and, indeed, all inferior or exhausted soils, must either have remained in their natural state, or been partially and most unprofitably cultivated, under the management of persons employed by great proprietors, but who felt no anxious interest in the success of their operations.

In this great manufacturing and commercial country, it is not the object that every man should labour the soil, but that the largest surplus, after the demands of the farmer are satisfied, should be furnished for the other classes of society, occupied in different ways. Of this, the best standard is the amount of rent. It is idle to suppose, that a great farmer can, by any savings in family expences, afford a higher rent than a number of small farmers on the same land. The personal labour of small tenants, the moderate accommodations with which they are contented, their careful, frugal manner of living, and their close attention to those small profits, which never enter the pocket of the great cultivator, warrant the conclusion, that if they cannot pay so high a rent as he does, it is because they cannot bring to market so large a surplus. Wherever the case is otherwise, the interest of the landlord, which is precisely the same with that of the public, will always prevent him from laying into one the separate possessions of a number of small occupiers. It is, however, indisputable, that the frequent use of this right has materially promoted the agricultural improvement of Scotland.

Explanation of Figures relative to Agriculture.

Plate I. fig. 1. A sowing machine, of a very simple construction, pushed forward like a wheel-barrow; in which A is the box containing

ARCHITECTURE.

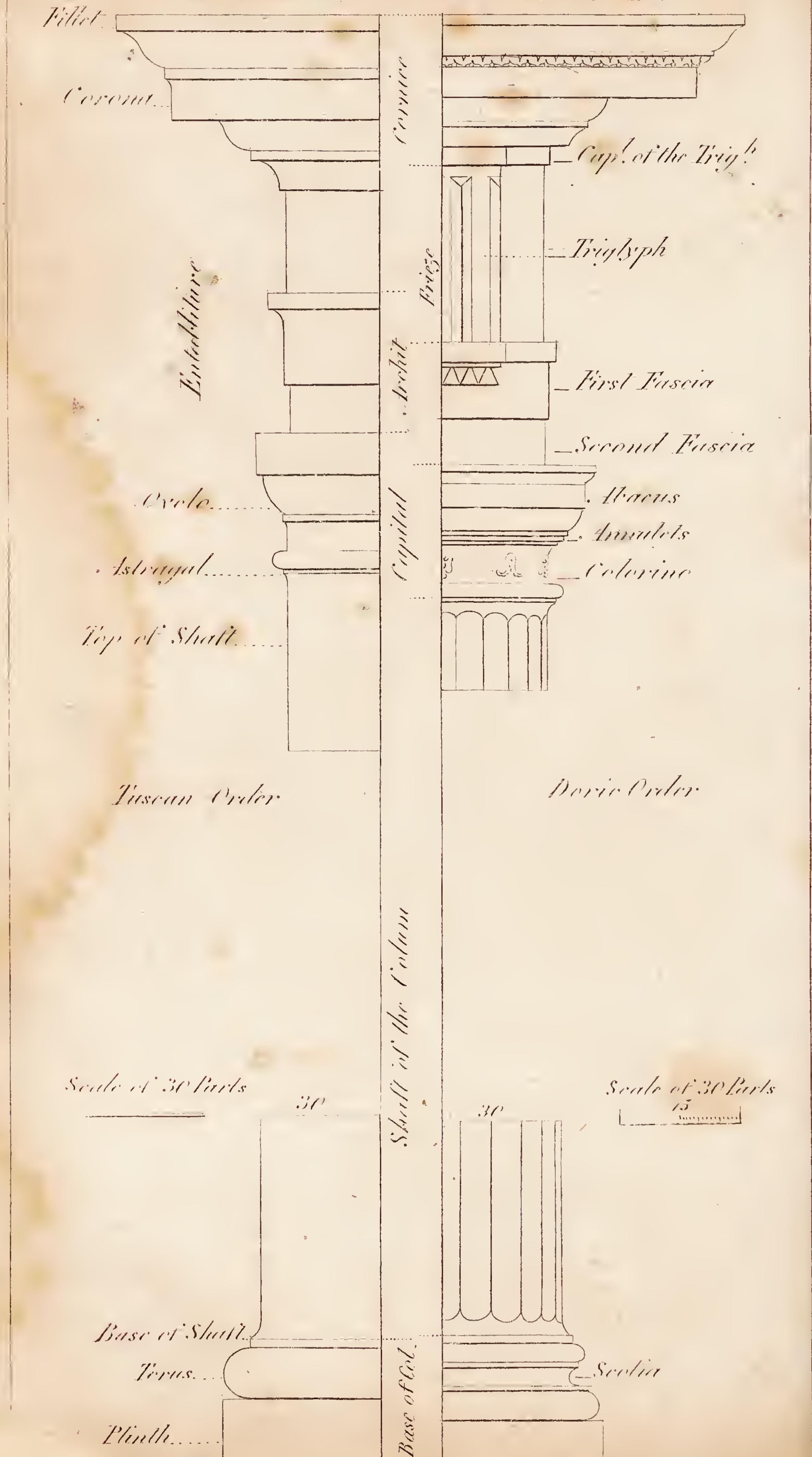


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Plate 3

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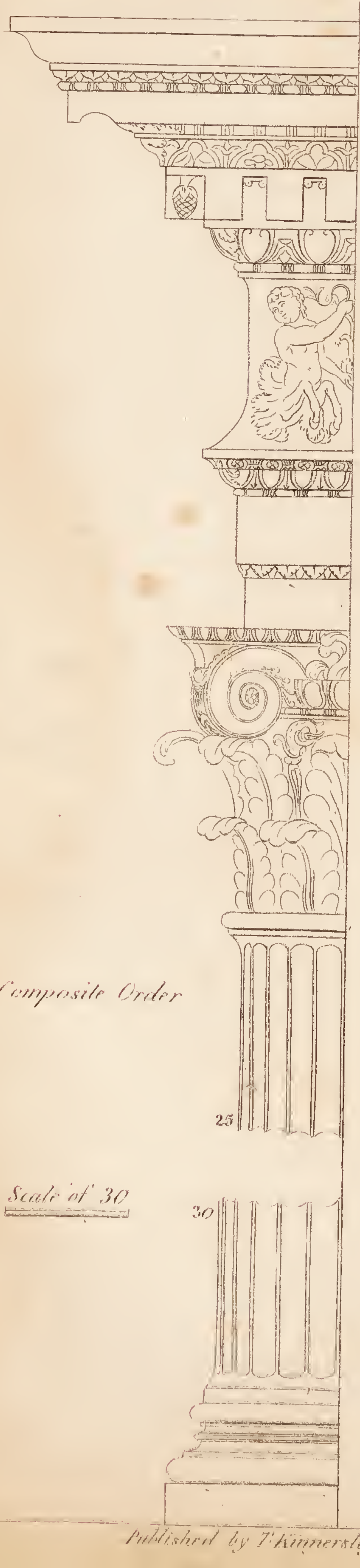
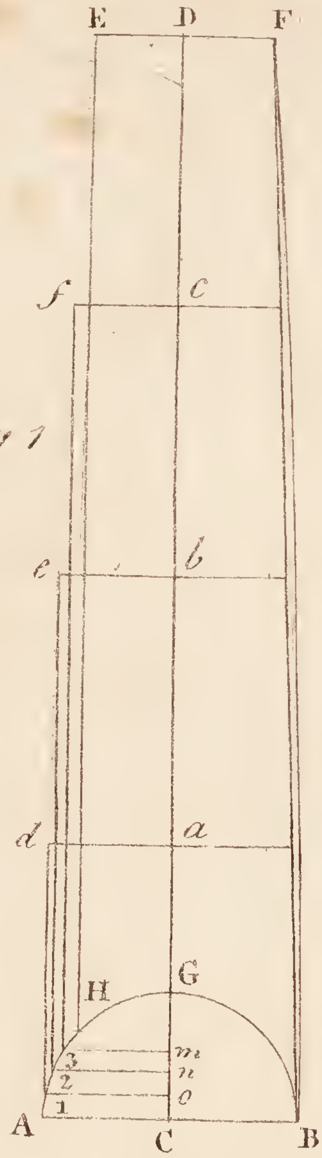


Composite Order

Scale of 30

Fig 1



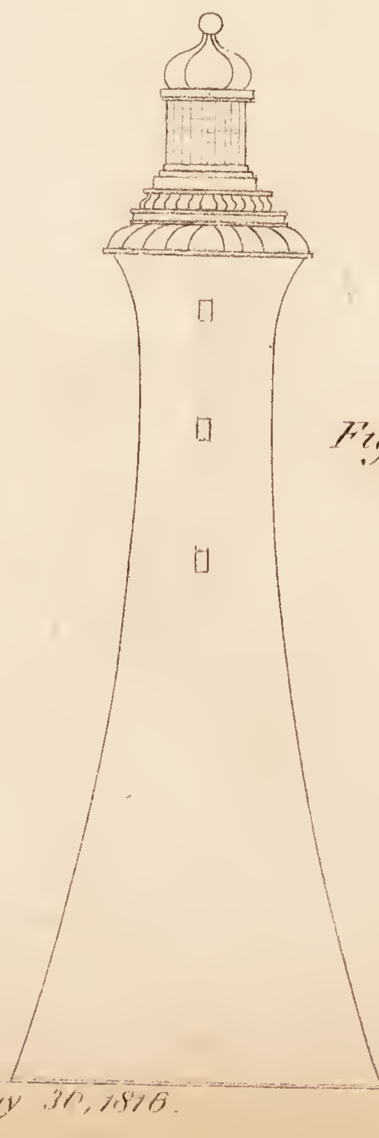


Fig 2

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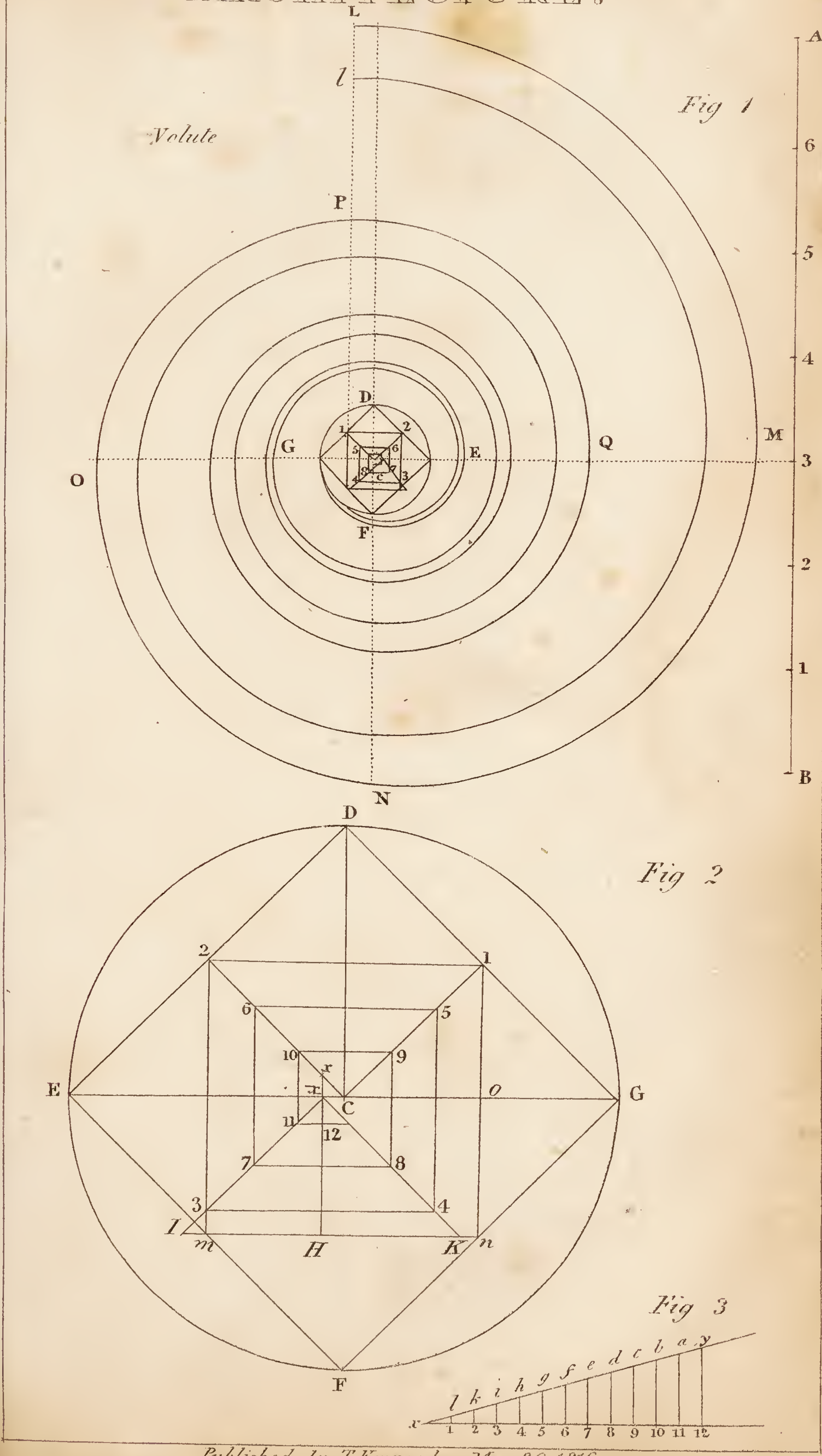

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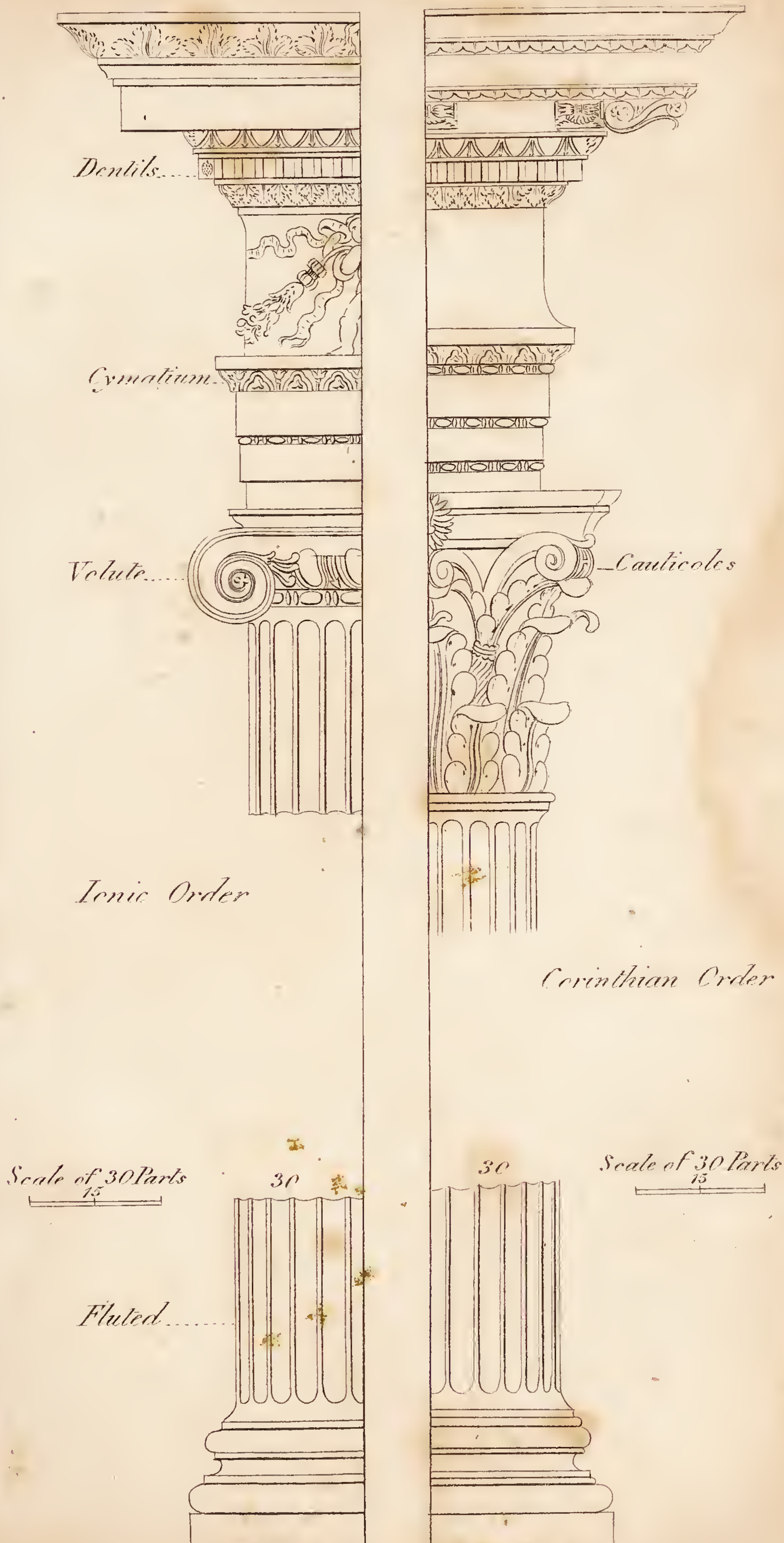

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the seed, which drops through holes in the cylinder B, made to turn round by a strap G, connected with the axle D of the wheel C. The seed is made to fall regularly by the inclined plate F, and it is covered by the dragging chains E.

Fig. 2. Represents a plough of an improved construction.

Fig. 3. Is a perpendicular section, or end-view, of a threshing mill, in which K is the axle of the principal wheel, moved externally by water, horses, or other convenient power. By another layer and pinions, the arms C and D are driven rapidly round within a circular box or frame, to beat the grain and straw, drawn in by the motion of the feeders A and B. The straw is carried off by the rakes E and F; and the grain drops through holes in the circular bottoms HI and IG.

Plate II. fig. 1. Is a section of a corn-mill driven by water, in which AB is the edge of the water-wheel, with its float-boards. C is the axle, of which one end plays in the outer wall at D, and the other, entering the mill-house, is supported on a wall at E. On this axle stands a perpendicular wheel F, furnished with cogs all round, which work in the upright staves or rounds of the trundle G. This trundle is supported on a strong beam, called the brayer, one end of which rests in a mortice at L, and the other at M hangs by an iron rod N, passing up through the floor at I, and secured by a screw-nut at O, by turning which, the brayer, and consequently the trundle and the upper millstone, may be raised or lowered at pleasure. The corn is put into the hopper P. from which it falls gradually into the shoe Q, from the end of which it drops into an opening in the centre of the upper mill-stone, to be ground down between it and the under stone, by the rapid motion of the upper stone, acted on by the revolution of the spindle or axle of the trundle G. The mill-stones are both inclosed in the box K.

CHAP. IV.

ARCHITECTURE.

The term *architecture* is originally derived from the Greek language, in which it signifies the principal handicraft, or mechanical operation, an expression very applicable to the construction of habitations for civilized men, without which, few of the other practical arts could be desirable or, indeed, of any value whatever. In the genial climates of the interior of Asia, where human beings first appeared, defence from the inclemency of the weather was not an object of research. Shelter from the intense rays of the sun, and from the torrents of rain peculiar to those climates; protection from the wild beasts of the field; the necessity of privacy, and complete separation from their fellow creatures:—these and other motives, which might easily be specified, would, nevertheless, render architecture, however rude and simple, one of the earliest

arts of life. To attempt to trace architecture back to its origin, would, therefore, be an idle enterprise. From the Hebrew scriptures we learn, that it was arrived at considerable perfection even under the second generation of mankind; for there we learn, that Cain, after the murder of his brother, withdrew from the habitation of his parents, and built a city in a remote quarter of the world.

The progress of architecture from rudeness to refinement is thus related by Vitruvius, whose celebrated treatise on architecture appeared in Italy in the reign of Augustus Cæsar, about the beginning of the Christian era. His notions were formed on tradition and conjecture: for the writings of *Moses*, which contain the most ancient account of the origin of the human race, and of human society, were either unknown, or generally disregarded in his time in Europe.

"In the first times," says Vitruvius, "men lived in woods and caves; but at last, borrowing hints from the birds, which build their nests with equal ingenuity and industry, they began to form huts for themselves. These huts were, probably, at first conical, because that figure is of the most obvious construction, composed of trees or branches fixed in a circle on the ground, and joined together in a point at the top; the whole covered with reeds, leaves, and clay. Finding, however, in the course of time, this conical figure inconvenient, on account of the slope of its sides, the form of the hut was changed to that of a cube, or of a parallelopiped. Marking out the space to be occupied by the intended structure, they fixed in the ground upright trunks of trees, to form the sides, filling the intervals with branches closely interwoven, and covering the whole with clay. The sides being thus completed, four long beams were placed on the upright posts, which, being well joined at the angles, kept the sides firm, and likewise served to support the covering roof of the building, composed of other beams, on which were laid beds of reeds, leaves, and clay. When the art of constructing habitations was thus far advanced, men bethought themselves of methods of rendering their dwellings, not only commodious for present use, but elegant and durable. They stripped the bark and other inequalities from the trunks and branches employed in the walls, raised them above the damp ground, by placing them on flat stones, and covered each post with a flat stone, to throw off the rain. The spaces between the ends of the joists were closed with clay, and the ends of the joists themselves were covered with thin boards, cut in the form of what are called triglyphs. The position of the roofs was also altered: being flat, they were ill calculated for throwing off the rain; they were, therefore, raised up in the middle, so as, with the horizontal beams connecting the uprights of the walls, to form a triangular pediment or gable. From these simple elements, architecture took its beginning; for when wood was found inconvenient for constructing durable dwellings, and men set themselves to erect more solid and extensive buildings, of clay dried in the sun, or of stone; they still imitated the forms of those parts which necessity had originally introduced. The upright posts, with the flat stones under and above them, were converted into columns with their bases and capitals; the beams, rafters, and layers of materials composing the roof, were gradually improved into architraves, friezes, triglyphs, cornices, and the other ornamental parts of modern architecture." ——So far Vitruvius; and as far as the improved architecture of the Greeks and Romans is concerned, his theory is perfectly applicable.

Architecture is arranged in different orders, according to the nations by whom, or the country in which, it was originally employed; such as the Greek, the Roman, the Saxon, the Norman, the Saracenic or Arabian, the Gothic, &c. The Greek architecture is divided into the Doric, the Ionian, and the Corinthian, so named from the inventors, or from those parts of Greece, or of the Grecian colonies in Asia Minor, where each kind first appeared. Roman, or Italian architecture was divided into the Tuscan, and the Composite, the first being employed, as it is said, by the ancient inhabitants of Tuscany, and the last being a later improvement adopted by the Romans, compounded of the two Greek orders, the Ionic and the Corinthian.

An order in architecture consists of two principal parts, the column and the entablature, or parts supported by the column. Of these two principal parts, each consists of three subdivisions: those of the column are the base on which it rests, the shaft, or tall tapering portion, and the capital, or ornamental part crowning the shaft: those of the entablature are first, the architrave, then the frieze, and above all, the cornice. Each of these smaller parts is again subdivided and distributed in various ways, according to the orders to which they belong, as existing in antique monuments, but more frequently according to the taste and fancy of the authors who have written on the subject of architecture.

The principal character of the various kinds of architecture depending on the column and its requisite accompaniments, the whole is commonly and almost universally divided into five species or orders, viz. the *Tuscan*, the *Doric*, the *Ionic*, the *Corinthian*, and the *Composite*. This distribution and arrangement would seem to have been founded on the progressive proportional strength and ornament of the orders: they are, however, well calculated to mislead the student and the architect, in tracing the origin and gradual advancement of each order. Without attempting to search for the commencement of either of the orders, it is sufficient for us to know, that the Greeks employed only the Doric, the Ionic, and the Corinthian; and that the Tuscan and the Composite were used in Italy only; the one more rude, and the other more ornamented than the Greek orders, which occupied a middle rank. To attain, therefore, a proper knowledge of the principles of architecture, the student ought to confine himself to the three Greek orders; not only because in them these principles are the most fully displayed, but because of all the monuments of antiquity which have subsisted to modern times, few, or perhaps none, can be pointed out in which the Roman or Italic mode of construction is certainly to be traced.

In architecture various terms are employed in a peculiar sense, of which the following are the chief:—*Column* is a Latin word signifying in general a pillar, or supporter of some superincumbent load; but it is now confined to a round pillar, smaller above than below, and thereby closely imitating the trunk of a tree, from which it was originally drawn. When the pillar is not round and tapering, but square, and of equal dimensions above and below, it is called a *pilaster*.

The column consists of three principal divisions: 1st, the *base*, from the Latin term *basis*, the foundation on which any thing rests: 2d, the *shaft*, or circular tapering portion: and 3d, the *capital*, from the Latin term for the head, or the principal member.

The *base* is subdivided into different small parts, according to the order to which the column belongs; but in all the lowermost part is the

plinth, from the Greek term for a brick, because the ancient bricks were in general about square, and comparatively thin, resembling our paving bricks or tiles. Above the plinth lay the *torus,* a round moulding resembling a rope, so called in Greek, and imitating the band tied round the bottom of the original tree, as the plinth did the flat brick or stone on which it stood, to keep it from the ground. Between these two members was sometimes introduced a hollow channel, called *scotia,* from the Greek word for darkness, because little light could enter it.

The column was generally quite plain and smooth in its whole length; but in buildings where ornament was particularly admitted, the shaft was cut into a succession of small perpendicular channels, resembling the inside of a pipe or flute cut lengthwise into two parts: hence the shaft is said to be *fluted.* In some instances one-third part of the flutings from the bottom was as it were filled up with the half of a round rod lying in the hollow. It is singular, that although the flutings may have been originally intended as an imitation of the natural hollows of the bark of a tree, and might therefore be expected in the earliest productions of architecture, it is only in the more improved works that fluted columns are to be found.

The *capital* is variously subdivided, and ornamented in the different orders, simple in the Doric, more ornamented in the Ionic, and highly enriched in the Corinthian. In all however a narrow moulding runs round the shaft, near its upper end, called the *astragal,* because it seemed to occupy the position of the upper bone of the neck. Because the word astragal also means in the Greek the *heel,* it is in some treatises of architecture most ridiculously expressed by that name. The uppermost member of the capital is the *abacus,* so called as being broad and thin, like the board or tablet employed by the ancients in arithmetical calculations.

The *volute* is an ornament introduced in the Ionic order, being, as its Latin name implies, a spiral scroll imitating the ends of some flexible substance loosely rolled up. The capital of the Corinthian order is encircled by rows of leaves of different sorts.

The parts which rest upon, and are supported by the column are comprehended under the general name of the *entablature,* because agreeably to the meaning of the term *tabula* in Latin, they consist of boards, planks, or stone slabs of different forms and magnitudes. The entablature is a compound of three principal parts, first the architrave, next the frieze, and uppermost the cornice. The *architrave* is so called by a name, partly Greek, and partly Latin, as being the *principal beam* which, resting on the capitals of the columns, supports the remaining parts of the entablature. In some cases it is plain, in others it is broken into two or three pieces, like so many separate beams lying on each other.

The *frieze* consists of one piece, but commonly enriched with sculpture of different sorts. In the Doric order this ornament consists of two whole channels, and two half channels, forming one if joined together, and therefore called by a Greek name *triglyphs,* or three hollows. The square spaces between the successive triglyphs are called *metopes,* a term expressing the hollow open spaces between the beams, the ends of which are represented by the triglyphs. In these metopes are sometimes represented the head of some divinity, the scull of some animal used in sacrifice, or other emblem of the purpose to which was destined the building on which the ornaments are introduced.

The *cornice,* from the French *corniche,* and the Latin *corona,* is so called because, being the uppermost part of the entablature, it *crowns* the whole architectural distribution of the column; and it is divided and ornamented in different ways, according to the order employed.

1. The first *Grecian* order in point of antiquity is the *Doric,* so named from the *Dores,* a small tribe in Greece, or as some say from *Dorus,* an Achaian chief, who first employed that order in erecting a temple to Juno at Argos. The height of the Doric column, including the capital, is $7\frac{1}{2}$ diameters of the lower end of the shaft, or 15 modules. In all the most perfect specimens of this order now remaining, the column springs immediately from the foundation, having no base properly so called, but only a small swelling round the bottom, resembling what we see at the root of a tree, and sufficient to show that we see the whole of the shaft. The base, we learn from Vitruvius, first appeared in the Ionic column. The Doric column being short in proportion to its diameter, and consequently strong, the entablature placed upon it is of course more massive than that of the other orders, being in height one-fourth part of the total height of the column.

2. The *Ionic* order derives its name from the *Iones,* a Greek people on the east coast of the Archipelago, whose capital was Ephesus, celebrated on many accounts, but particularly for the magnificent temple of Diana. This admirable structure was in length 425 feet, and in breadth 220 feet: it was surrounded on all sides by a double range of marble columns, 70 feet in height, and consequently 7 feet $9\frac{1}{3}$ inches in diameter at the bottom.

The Ionic column is taller than the Doric, containing 9 diameters, or 18 modules; and although simple, is nevertheless graceful and majestic. If the Doric were meant to represent the manly robust figure of Hercules, the Ionic might properly be the emblem of the dignified simplicity, and elegance of Diana. In this order, as was already observed, the base supporting the column was first introduced. An ornament peculiar to the Ionic column, is the *volute,* or spiral scroll already mentioned, which is described by a succession of portions of circles, drawn from different central points. The height of the whole entablature is $\frac{2}{9}$ths of that of the column, being the medium between that of the Doric, which is $\frac{2}{8}$, and that of the Corinthian which is $\frac{2}{10}$. The height of the base is one module or half the diameter of the shaft.

3. The *Corinthian* order took its rise in the flourishing days of *Corinth,* a celebrated city commanding the communication of the peninsula of Peloponesus, with the continent of Greece. The beautiful foliage of the capital of this order is traced back to the following incident. A young lady of Corinth dying, her nurse carried her play-things in a basket, the day after her funeral, and placed it on the grave. The basket covered with a flat tile, was placed accidentally on the stem of the plant *acanthus,* which sending out leaves soon inclosed the basket, having their ends turned downwards when they reached up to the tile. This object struck the fancy of a celebrated sculptor of those days *Callimachus,* who immediately introduced a figure of it on the top of an elegant column of his invention. Thus the capital of the Corinthian column always resembles a deep narrow basket covered with a tile, and completely surrounded by foliage. Such is the account given by Vitruvius; but later writers on architecture have imagined they could discover this ornamented capital, in the description given of the temple erected by

Solomon in Jerusalem; with this difference that there the foliage represented branches of the palm, and not the leaves of the acanthus. It is however to be observed, that the foliage of the Corinthian capital is frequently an imitation of the leaves, not of the acanthus, but of the olive, and of other plants, according to the taste of the architect. The Corinthian column is in height 10 diameters or 20 modules, of which the base is 1 module, and the capital $2\frac{1}{3}$ modules, consequently the shaft measures $16\frac{2}{3}$ modules. The entablature is $\frac{1}{4}$ of the column.

1. The first *Italic* order is called the *Tuscan*, as having been employed by that ancient people, once very powerful in Italy. It is however remarkable, that no vestiges now exist of any building in which the Tuscan column was employed to support an entablature, or any other weight. Vitruvius, it is true, gives instructions for erecting temples according to this order; but it does not appear that such edifices were actually erected. The only examples of the use of the Tuscan column that have come down to our times, are the admirable monuments, still subsisting in their original perfection, the columns of *Trajan* and *Antoninus* in Rome, and the column of *Theodosius* in Constantinople. The column erected to the honour of Trajan, (next to Julius Cæsar, perhaps the most valuable of the Roman emperors) who flourished a century after Christ, is in all 118 feet high. The shaft of the column is in length $14\frac{1}{3}$ modules, or $7\frac{1}{6}$ diameters, each 11 feet 2 inches. The pedestal supporting the column is a cube of 3 modules; the base is 1 module, and the capital $\frac{2}{3}$ module. On the capital is another pedestal on which stood a colossal statue of Trajan; but this was removed, and one of St. Peter now occupies the same place. The other column, commonly said to have been erected to Antoninus, is of the same kind, but a little smaller: it now supports the statue of St. Paul. The magnificent but unhappily situated column, or the monument, erected in London, to commemorate the dreadful conflagration, which in 1666, laid waste the greater part of that city, although copied from those in Rome, and of considerably larger dimensions, is not properly Tuscan but a fluted Doric.

2. The other *Italic* order is called the *Composite*, because it seems to be a combination of the Ionic and the Corinthian orders, to which last it bears the greatest resemblance; imitating the former only in the adoption of the complete volute in the capital, in addition to the Corinthian foliage. A specimen of the Composite order, richly ornamented, is to be seen in the triumphal arch, erected at Rome to the honour of Titus, in consequence of his signal victory over the Jewish nation, in the year 70; under the arch of which are represented in sculpture, the golden candlestick of seven branches, and other precious articles, carried away from the last temple of Jerusalem.

Besides columns properly so called, which are always circular, another kind of pillars called *pilasters* are frequently employed, especially where a great weight is to be supported. The plan of a pilaster is usually a square; but those, the plan of which is a parallelogram, are also introduced. The chief use of pilasters is to support arches. Thus the piers of a bridge are in fact short pilasters: the arches separating the nave from the side-ailes of S. Paul's church in London, of St. Peter's in Rome, are supported on pilasters. In some buildings, it is true, we find ranges of arches supported on columns of even the delicate Corinthian order; but as columns are of a tapering form, the upper diameter being less than the lower; and as this diminution is increased in the eye


A
Beautiful Specimen
of the Ionic Order, drawn by
Measurement, from the Temple of
Fortune at Rome.

of the spectator, by the distance of the upper part; columns have a slender, and even a feeble appearance, and are consequently ill adapted for supporting an arch. On the other hand, pilasters being of equal dimensions all over their height, and very short in proportion to their diameter, possess a solidity and strength capable of bearing arches of the greatest weight and magnitude.

By pilasters we also mean an ornament applied to walls, internal and external, resembling in parts and form a column, but flattened instead of round. Pilasters of this sort have their base shaft and capital, and are plain or fluted, according to the architectural order to which they belong. It is a matter still unsettled whether such a pilaster ought to diminish in breadth like a column, or to retain the same breadth above and below like a solid pier. Pilasters usually project one-fourth part of their breadth from the wall to which they are applied.

Both columns and pilasters are frequently raised from the ground, and placed on *pedestals*; a construction not without its propriety in certain cases; as in our churches where the galleries rest upon pilasters, and the front of the gallery coincides with the pedestal of the column which rises to the roof. Pedestals are by no means essential to columns or pilasters; but when employed they must be formed and ornamented conformably to the order of the columns they support.

Columns are placed at different distances according to their destination; and the spaces between them are termed *intercolumniations*. This separation in the Greek orders varies from one diameter and a half of the lower end of the column, to four diameters: but if the Tuscan column were employed, the architrave being supposed to consist of beams of timber, the intercolumniation may be much wider than if it consisted of blocks of stone. That interval, however, between columns, which has received the sanction of the best monuments of antiquity, and of the most judicious architects, is equal to two diameters and a quarter of the column. Hence it is called *Eustyle*, from two Greek terms expressing the proper arrangement of columns. The latter term *stylos*, a column enters into the composition of several other architectural terms, as *pycnostyle*, to express columns placed very close together; *prostyle*, a number of columns placed as in a portico before the entrance-front of a building, of which we have examples in London in the churches of St. Martin in the Fields, of St. George Hanover Square, of St. George Bloomsbury, in imitation of ancient edifices in Rome, &c. When ranges of columns are carried quite round the outside of a building, they form a *peristyle*.

Arches may perhaps be considered as less magnificent than ranges of columns; but they are very solid, and liable to few accidents. The importance of arches, in affording a commodious passage over a river, needs no illustration. It has long been the practice to construct bridges of arches increasing in width, and consequently in height, from each end to the middle, so that the road formed the segment of a large circle. The arches have also been generally semicircles, or segments of circles nearly approaching to semicircles. This practice was first laid aside in France, where many noble bridges are now to be seen, consisting, like the ancient Greek and Roman, of arches, all of the same span or width, and the same height; so that the road is carried on a level all the way along the bridge. In order to keep the bridge low, the arches vary greatly from a semicircle, being segments of circles of large diameter,

Nay, in some instances in France, the arches are portions of ellipses, and not circular, by which measure the crown of the arch is kept very low. On this most improved plan a bridge is now constructing in London, over the Thames, between Blackfriar's and Westminster bridges, which for excellence of materials and structure, for magnificent simplicity and extent, will be perhaps without a parallel in Europe. It consists indeed of only nine equal elliptic arches; but each is of 120 feet span: the extent of each pier between the arches is 20 feet, and the whole length of the bridge 1280 feet, very nearly a quarter of a mile, on the same level line from the one end to the other. To enable the reader to form some judgment of the properties of this new work, (called the *Strand bridge*, because it leads into that street, on the west of Somerset Place,) the following account of some other remarkable bridges is given. Of the adjoining communications over the Thames, London bridge consists of 19 arches, and is in length 915 feet; Blackfriar's bridge consists of 9 arches, and is 995 feet long; and Westminster bridge consisting of 15 arches is in length 1223 feet. The celebrated bridge over the Loire at Tours in France is horizontal, consisting of 15 elliptic arches, and in length 1335 feet. The bridge over the Moldaw at Prague, the capital of Bohemia, is in length 1700 feet. But these are all far surpassed in length by the antique bridge over the rapid Rhone, at St. Esprit in the south of France, which, constructed on a multitude of small arches, extends to the length of 3000 feet: possessing this singularity, that, instead of being straight, it consists of two lines of direction, meeting in the river at a very obtuse angle, pointed up against the stream, as if the better to resist its violence.

In various edifices ancient and modern, we find columns and arches placed in ranges one above another. In such works care must be taken that the more massive should support the more slender; placing first the Doric order, next the Ionic, and above all the Corinthian or Composite. In this arrangement the lower diameter of the superior column is usually made equal to the upper diameter of the inferior column; giving the succession of columns the air of one tall tapering tree, cut into so many separate portions.

The most remarkable edifices of antiquity, which have subsisted with tolerable entireness to our days, are temples of various sorts. The structure of these temples is extremely simple, the building being a parallelogram seldom of great dimensions. Some have a portico of columns at the entrance, and the external walls plain or adorned with pilasters. Other temples however are surrounded on all parts by a single, and even by a double range of columns, supporting the architrave frieze and cornice, together with the roof; so that the temple itself is in a manner concealed from the view, and receives no light but from the entrance. Such a construction is evidently very ill adapted to the purposes of a Christian, and especially of a Protestant place of worship. It has nevertheless been imitated in many magnificent structures, with some alterations, and the addition of projections on each of the long sides, for the purpose of resembling the *Cross* the emblem of the Christian faith. According to the system of divine service which for many centuries has prevailed in the Roman Catholic worship, the sacred offices may be conducted, without mutual interference, in sundry parts of a church at the same time. In the Protestant system, however, whether Lutheran, Calvinistic, or Anglican, in which nothing is done as it were

in secret, and in which every member of the congregation is to hear, and participate in every part of the service, sacred edifices must, to be useful, be limited in magnitude and form. To be satisfied of the truth of this observation, it will be quite sufficient to enter St. Paul's church in London, at a time when service is performing. A comparatively small portion of that grand structure is set apart for the congregation, while the great body of the building presents the appearance of a vast useles void, neither applied, nor indeed applicable to any purpose of the Protestant worship. The same observation belongs to our Gothic cathedrals; but these were constructed with a very different view.

The columns of the portico, and the pilasters of the body of St. Peter's at Rome reach at once from the ground to the attic; but in St. Paul's of London, the whole of the edifice is divided into two ranges of columns and pilasters; an arrangement which, by breaking the whole into a repetition of small parts and members, counteracts the effect which would be produced by the great dimensions of the edifice, were it adorned with columns, occupying the whole height of the building. On the other hand, the intervals between the grand columns of the portico of St. Peter's having been built up into two stories of arcades and balconies, to accommodate the Pope in certain ceremonies, the effect of the portico is destroyed; and instead of one open range of lofty pillars, the eye is offended to see them half sunk as it were into a wall, the use of which is by no means at first sight apparent. From this material defect, the front of St. Paul's, although broken into two ranges of pillars, is fortunately free.

Columns grouped, or placed two and two together, have always a bad effect; for they suggest to the observer the idea that single columns had been at first employed, and that, being found to be too weak for their load, another set of columns had been placed beside them, to take off a part of the burthen. Grouped or double columns are wholly a modern invention; nothing of the kind being found in any antique work: and although they were employed by the first-rate architects who constructed the celebrated colonnade of the palace of the Louvre in Paris, the front portico of St. Paul's, the entrance into Somerset Place in London, &c. the grouping of columns is nevertheless a departure from the genuine rules of art.

Instead of different ranges of columns it is usual to throw the ground-floor of an edifice into the form of a *basement,* on which rise the columns or pilasters to ornament the front. This basement ought never to be less in height than half the length of the order it supports. Basements are generally *rusticated;* that is, the stones are cut and placed so as to resemble the rude blocks as they may be supposed to rise from the quarry. In the application of this rustication, however, the judgment and taste of the architect will be displayed. In London we have examples of the judicious employment of rusticated walls, and of the very reverse. The huge ponderous masses, apparently in all their native rudeness, composing the exterior of a *Newgate prison,* admirably indicate and characterize the nature of the edifice. The less rude, it is true, but still rusticated walls of a *Carleton-house,* are on the contrary, equally incongruous with the delicate, and richly ornamented portico, and with the purposes to which that structure is appropriated.

When a building is divided into different floors or stories, it seems proper that each story should have its separate range of columns or pil-

asters, which then appear each to support, in the entablature, the projecting timbers of the superincumbent floors. When, on the contrary, two and even three tiers of windows are all included in the height of one range of columns or pilasters, the want of use, and even of connection, in columns of such a length, must strike every observer. Of this last defect we have a striking example in the portico of the *Admiralty Office* in London. Four great disproportioned columns comprehend *three* ranges of windows: but thanks to the classic genius of *Robert Adam* of the Adelphi, by his interposition of a skreen, equally simple and elegant, so much of the columns is concealed from the eye as to bring them within limits, in some degree suited to the structure to which, without belonging, they are attached.

When a range of columns, surmounted with their proper entablature, supports the end of a roof, a triangular space is formed called a *pediment*, the two inclined sides being finished agreeably to the cornice below them: the inclosed triangular space or *tympanum* is often filled with historic or emblematic sculpture. Pediments on a small scale, triangular or as arches of circles, are frequently placed alternately over windows in modern buildings; and instances of the same intermixture are not wanting in vestiges of ancient structures. The most proper proportion of a pediment, whether triangular or circular, is to make its perpendicular height from one-fifth to one-fourth part of the base.

Gothic Architecture.

The preceding observations belong to the Grecian and Roman systems of architecture: but another system, conducted on very different ideas, and of which many specimens, of admirable contrivance and execution, still adorn the principal states of Europe, namely the *Gothic*, remains to be noticed. The term is often improperly employed to express every mode of construction not reducible to the ancient Grecian: in this way, works erected by the Saxons and the Normans, in the northern and middle parts, and by the Saracens or Moors from Africa, in the southern parts of Europe, are often confounded under the general name of Gothic, with those to which that name properly belongs. This last species of building is supposed to have first appeared in England, after the conquest, in the reign of Henry the 2d, who died in 1189; introduced most probably from Normandy, and other parts of France, where splendid monuments of Gothic architecture, are very common.

On the origin of the Gothic mode of building, ingenious men have varied much in opinion; and even on the origin of the name. The Goths were in early times the inhabitants of Sweden: but in the decay of the Roman empire, they, with other northern tribes, invaded and over-ran all the southern parts of Europe, even to the strait of Gibraltar. Ignorant of every art but that of war, the science and skill introduced into these parts by the Romans, were overwhelmed, and architecture gradually assumed forms unknown to the Romans and the Greeks. Hence buildings constructed on principles different from those of antiquity came to be distinguished as Gothic; not because the Goths alone were their founders, but because the Goths and their neighbours the Vandals, having established a regular succession of kings in Spain, their name became more famous than that of any other northern race.

The Saxon, Norman, and Gothic styles of architecture, though nearly related in sundry particulars, have still each its peculiar character. The Saxon and Norman proper agree in this, that the form of the building is in both the same; the pillars are round, square, or polygonal, and very short, massive, and strong, but the arches and heads of the doors and windows are semicircular. If, in these particulars, any difference be found, it consists in the superior massiveness and large dimensions of the Norman architecture. The Saxon churches, of which sundry examples, or parts at least, have remained to our times, were often well constructed, and even elegant, but generally of a moderate size. Those erected by the Normans, on the other hand, were usually large and magnificent, carried up to a great height with two, and even three ranges of pillars, one above the other, of various dimensions, but connected by circular arches. In the centre was a lofty tower, with two others at the west end, where was the principal entrance. In the course of time, however, the Normans introduced pillars of a much more agreeable form, tall and slender. In England, the Saxon and Norman styles are generally found mixed in the same building; the latter, introduced in the twelfth century, being ingrafted on the former, which had been in use for some centuries preceding.

The principal marks by which the true Gothic architecture is distinguished, are its projecting buttresses around the exterior of the building, its pinnacles and spires, its large branching windows, its niches, its canopies, and sculptured angels, saints, and kings, the fretted roof, the clustering pillar, but above all, the arch always more or less acutely pointed. As plainness and solidity constitute the leading features of the Saxon and Norman buildings, so the Gothic architecture is distinguished by the lightness of the work, the lofty boldness of its elevation, the peculiar slenderness of its pillars, the profusion and delicate richness of its ornaments, and, we must add, the astonishing excellence of the masonry.

In inquiries into the origin of the proper Gothic style of building, we meet with no less genius and fancy than in similar inquiries concerning the Greek orders, and a much greater variety of sentiment. Some writers imagine the Gothic style was brought into Europe by the crusaders, on their return from the Holy Land, and other parts of the east; and think that this style should be called Saracenic. Others would call it Moresque, as having been introduced into Spain by the Moors. On the other hand, the pointed arch, which characterises the Gothic, is by some traced to the intersection of two semicircles, such as is frequently seen in Saxon buildings; the one arch being described from the end of the diameter, and passing through the centre of the other. Such an intersection would form an angle of 60°, and lines from it to the other extremities of the arches, would, of course, form an equilateral triangle; a form certainly not unfrequent in Gothic buildings. The scheme, however, which has gained the most general assent is, that the Gothic is derived from the ancient practice of religious ceremonies being performed in groves of lofty trees. The eye being accustomed to contemplate the arches formed by the branches of the trees that shaded their altars, and sheltered their assemblies, it was natural, when covered buildings succeeded to these groves as places of worship, that men should endeavour to introduce some similitude between them and those places in which they had been accustomed so long to perform their religious

ceremonies. Accordingly we find not only the intersecting arches, formed by the branches, exactly imitated by the pointed arch, but also the stems of the trees as accurately represented by the slender and clustering pillars of a Gothic cathedral. Indeed, no attentive observer ever viewed a regular avenue of well-grown trees, intermixing their branches over head, but it presently put him in mind of the long vista through a Gothic church; or ever entered one of the larger and more elegant edifices of this kind, but it presented to his imagination an avenue of lofty trees, intermingling their branches over his head. Under this idea of so extraordinary a species of architecture, all the irregular transgressions of art, all the monstrous offences against nature, as some men speak, disappear: every thing has its reason, every thing is in order, and a harmonious whole arises from the studious application of means proper and proportioned to the end. For could the arches be otherwise than pointed, where the workmen were to imitate the curve made by two opposite trees, by their mutual insertion into one another?—could the columns be otherwise than split into distinct shafts, when they were to represent the stems of a clump of trees growing close together? On the same principles they formed the spreading ramifications of the stone-work in the windows, and the stained glass in the open interstices; the one to represent the branches, and the other the leaves, of an opening grove; both concurring to preserve that gloomy light, which, in the greater number of men, inspires religious awe and veneration. Hence we see the reason of their studied aversion to apparent solidity in these stupendous masses of building, deemed so absurd by men accustomed to the apparent as well as the real strength of Grecian architecture: for the surprising lightness of the Gothic building, united with real strength, was necessary to complete the execution of their original idea of a sylvan temple.

The origin of Gothic architecture here pointed out has been lately very happily illustrated and exemplified by *Sir James Hall*, in a dissertation published in the Transactions of the Royal Society of Edinburgh, and in a subsequent separate publication on the same curious subject, well worthy of attention.

In the architecture of the Greeks and Romans the columns were admired for the elegance of their proportions: but in the Gothic the column is seldom, if ever, diminished in diameter; nor do we find any fixed proportion between the diameter and the height of the column; nor is the intercolumniation, or space between any two pillars, regulated by their diameter or their height. Examples of the widest difference in the intercolumniations are common; for instance, in the nave of the cathedral of York, and in the aisles of the conventual church of Newark-upon-Trent; both edifices deservedly admired, but widely differing in the proportions of their columns, and in the intervals between them.

The Gothic column not being diminished above, and having no entablature, is the better suited, in point of stability, to support the arch springing immediately from it, as only a continuation of one half of the column. An arch springing from a Greek or Roman column, has always, as was before observed, an unfavourable effect. The striking impression of a Gothic structure is produced by taking in the whole in all its relations; but in the Greek architecture, our pleasure often arises from contemplating the elegance and fine proportions of its several parts. On viewing a Gothic building, we soon perceive how admirably the parts

are constructed for the eye to embrace the whole. The column is generally an assemblage of vertical mouldings, or a bundle of rods, inclosing a tall slender post, or trunk of a tree, acting as a conductor to the eye. The capitals present little or no interruption to the sight, which glides up along the pointed arch, and embraces the whole upper portion of the edifice. One of these vertical rods forming the column, pierces through the capital, and ascends to the roof, and from it spring the ribs of the vaulting. The exterior of a Gothic edifice has an effect similar to that of the interior: the vertical rods of the columns run up to the top of the pediment and the terminating pinnacle; and the pyramidal buttresses on the outside, produce similar effects on the eye of the beholder.

General observations on the construction of houses. In building, the situation is the first point to be determined. For dwellings the position ought to be sufficiently elevated to be free from damps and noxious vapours; but at the same time not exposed to the wintery blasts. The neighbourhood of fens, marshes, and stagnating waters should always be avoided: but water for domestic uses should always be easily and plentifully attainable. When a full southern aspect cannot be procured, the next best is a western, for the heat is always greater, at equal distances from noon, in the afternoon, than in the morning. With respect to the ground to be built upon, it should be carefully examined by boring or sinking pits. Stone or gravel generally afford the safest foundations: but if these be not of considerable thickness, dependance ought not in all cases to be placed on such soils. If, however, it become necessary to found upon sandy, or upon marshy, boggy ground, the foundation must be secured by piling, planking, laying large ledges, or other contrivances of the same nature.

The situation being determined on, the architect or builder prepares plans of the intended edifice, general and particular, with elevations of the fronts and ends; not drawn as they would appear to the eye of a spectator, agreeably to the rules of perspective, but according to their several dimensions as measured on a given scale. To the plans of each separate story must be added sections in length and breadth of the whole building, to shew the elevation of the internal parts. As, however, no building can ever appear to the eye in the precise form of a geometrical elevation upon paper; and as it requires considerable skill and practice to be able, from such an elevation, to form a judgment of the appearance of the edifice when actually erected, it is most satisfactory, and indeed but just to the proprietor, to furnish him with views of the intended structure from different points of sight, accompanied by its attendant outbuildings, shrubbery, plantations, &c. such as they may be expected to be when brought to perfection. From the want of such general perspective representations, many a proprietor has beheld with disgust or mortification the completion of a residence on which vast sums were expended; and the architect has very unjustly been blamed, nay, in some cases ruined in his business, in consequence of such vexatious disappointment occasioned to his unscientific employer. In cases of palaces, or other great buildings, models of timber are often constructed, which, when done upon a properly adapted scale, convey a very perfect conception of the intended structures.

The external form, and the internal distribution of houses, are necessarily susceptible of such variety, that it is impossible to lay down any

particular rules on those heads. A country seat is of late years usually arranged in a centre building for the family, with two wings, connected by covered passages with the centre, for various other purposes. The proportion that these wings should bear to the centre, has never yet been ascertained: yet every passing spectator will exclaim against the architect, when the disproportion between the wings and the centre strikes him as extravagant. In some modern buildings of this nature we find the length of the wings in front, each only one-third part of that of the centre; in others one-half: but nothing has a worse effect than disproportion between the body and the wings in point of height. The connecting passage or colonnade always looks best when it forms exactly a quarter of a circle.

The great difficulty in architecture is to combine utility with ornament or magnificence. This can indeed be properly done in structures of a certain extent alone. but even space and expence have not always been sufficient to ensure these essential ends. Excess of ornament is always misplaced in small buildings, which have then more the air of models of other great works, than real places of abode. It was observed of *Chiswick* house, on the bank of the Thames above London (built in imitation, but on a small scale, of a noted structure of *Palladio* near *Vicenza* in the north of Italy,) that it was too large to hang to one's watch-string, and too small for a man to live in.

Doors. The size and proportions of doors must be regulated by the purposes of the building to which they belong. The door of a dwelling-house, corresponding to the human size, is confined to seven or eight feet in height, and three or four in breadth. In private houses four feet may be the greatest breadth. In small doors the breadth or width may be to the height as three to seven; but in large doors as one to two. Doors intended to have but one leaf or close should never exceed three feet six inches in breadth; otherwise the door becomes too heavy for convenient use. Doors of a wider aperture, especially in the outer wall, are best formed with two folding leaves. As to the modern fashion of opening a wide communication between rooms on the same floor, by means of broad folding doors, the practice sets all rules of proportion completely at defiance. The external lintels of doors and windows should always be on the same level; and the doors should never be narrower than the windows. When the outward wall is ornamented with half-columns and arches forming blank arcades, the doors and windows should just rise up to the springing of the arches. The most common way of ornamenting the aperture of a door is by an architrave on the top, and also down the sides. Sometimes a cornice, and even a complete entablature may be placed above the lintel. Pilasters, and semi-columns have also a good effect, when applied to outer doors. Porticoes of four or more columns are properly adapted to large buildings.

Windows. The number and the size of windows in a building must be regulated by the nature and purposes of that building. The climate, the aspect, the extent, the elevation, even the thickness of the walls must all be taken into consideration. When the walls are thick, which is commonly the case in detached stone buildings, the windows may have a considerable opening inwardly, which will admit nearly as much light as if the whole aperture in the wall were enlarged. The proportions of windows depend on their situation: only their width ought to be exactly the same in every story, those in each, however, being pro-

portioned in height to that of the apartments in each story. In the principal floor the height of the windows may be from two and one-eighth, to two and one-third of the width. In the ground story, where the apartments are lower, the apertures of the windows seldom exceed a double square, that is the height is just double the breadth. When the basement is rusticated, the height is generally much less. In the second floor the height of the windows may be from one and a half, to one and four-fifths, or rather three-fourths of the width. The windows of the attics, and mezzaninos or entresols may be a perfect square, or even lower.

The windows of the principal floor are the most enriched. The simplest ornament of such windows is an architrave carried round the aperture, with a frieze, and cornice on the top. The windows of the ground floor are sometimes entirely plain; at other times they are surrounded with rustics or a regular architrave. Those of the second floor are generally inclosed with an architrave, crowned at times with a frieze and cornice: but these last ornaments would be improper in the attics. The breasts of all the windows on the same floor ought to be on the same level, and raised from two feet nine inches to three feet six inches above the floor. In warm climates, or in country houses in our own climates, seated amid gardens and pleasure grounds, the windows of the ground story, being cut down to the floor, render the apartments convenient and agreeable. In country houses indeed in France, Italy, and other warm parts of Europe, the principal apartments are all upon the ground floor; and the other floors diminish in height as they rise above it. The windows of the ground floor being cut down even with the doors, and thus affording a ready communication with the garden or lawn, have a peculiar propriety. How far the same practice in the windows of the first and other floors, in the streets of London, by which the cold and damp of winter must inevitably penetrate into the apartments, ought to be applauded, is a point to be decided by those who prefer comfort and health to absurdities, however fashionable. Not contented with adopting usages suited to the genial temperature of the south of Europe, a stranger on passing along the new quarters of London, might be tempted to imagine himself transported to the burning climes of India, when he beholds the fronts of the houses, whatever be their exposure, adorned or rather loaded and blocked up with vast projecting galleries, intended, but very unnaturally, to imitate the light, airy, and refreshing *varandas* of the East. In so far as these galleries are on the *outside* of the windows and walls, they are certainly of use to intercept the immediate action of the sun's rays. On the same account what we call Venetian blinds ought to be placed on the outside, and not on the inside of our windows. On the inside they keep off the glare of the sun's rays, but not the heat, which communicates to the air of the room, warming it just as much as if no blind intervened. On the outside, the blinds reflect and repel the heat as well as the light, and the air within the room preserves a desirable coolness of temperature.

The intervals of wall between windows should never be less than the aperture of the windows, nor in dwelling houses greater than twice that aperture, otherwise the light will be deficient. The usual rule for proportioning the quantity of light to a room is to multiply the length of the room by the breadth, and the product by the height: the square root of the last product gives the number of square feet of aperture requisite

for properly lighting the room. Thus suppose a room to be in length 32 feet 6 inches, in breadth 24 feet, and in height 15 feet: the product of these quantities multplied successively into each other will be 11700, the square root of which, in even numbers 108, will be the number of square feet of aperture required to lighten the room. This quantity distributed among 3 windows, gives 36 square feet for each window, the width of each being 4 feet, the height must be twice and one-fourth, or 9 feet. Had it been proper to open 4 windows in the same room, each must have contained only 27 square feet; and if the breadth of each were 3 feet 6 inches, the height would be 7 feet $8\frac{1}{2}$ inches. It is however here to be observed, that both internal and external openings in houses, such as windows, doors, &c. ought always to consist of the uneven numbers 1, 3, 5, 7, 9, &c. and never of the even numbers 2, 4, 6, 8, 10, &c. This rule cannot always, it is true, be observed in the confined spaces allotted to houses in towns; but in other situations, if the number of windows be even, the door cannot be opened in the centre of the building, and the want of an equal corresponding extent, and balance on each side, must strike the most careless spectator. The same rule is to be observed in distributing the arches of a bridge or an arcade, the intercolumniations of a portico or colonnade.

The proportions of rooms, in length, breadth, and height, are more the objects of taste and experience, than of geometrical regulation. A circle or a square is a more perfect figure than an oval or a parallelogram; and a globe, a cylinder, or a cube than a parallelopiped. A room however in the form of a cylinder or a cube, would in general be neither useful nor agreeable. The parallelopiped is therefore the form universally adopted for rooms or chambers of every sort; in which the greatest dimension is the length, the next is the breadth, and the smallest is the height. Some architects have made the breadth one-half more than the height, and the length one-half more than the breadth. Thus for example, if the height of the room be 16 feet, the breadth will be 24 feet, and the length 36 feet: and on the other hand, if the length be given 22 feet 6 inches, the breadth will be two-thirds of it, or 15 feet, and the height two-thirds of the breadth, or 10 feet. Such a rule however must evidently be subject to many modifications. The rooms on the ground or the second floor, may be of the same length and breadth with those on the principal floor: but if they were of the same height, the impropriety would immediately strike and offend the eye. No defect in proportion, however, is more offensive than that in the height; and none takes more off from the appearance of a room. A low apartment, whatever be its other dimensions, never can possess either dignity or beauty.

It is the common remark of every one who, for the first time, enters the matchless fabric of St. Peter's in Rome, that it by no means strikes the eye as so vast as it is known to be. This effect arises from the correct proportions of the whole edifice, in length, breadth, and height, and of the various members of which it consists. Had it been narrow, our attention would have been attracted to its great length: had the cieling been low we should have been offended by its disproportionate length, and breadth. Such on the contrary is the harmony of the several dimensions of the building, that no excess or defect in either of them leads us to institute a comparison between them. It is only by observing the time necessary merely to walk round, and give a cursory glance

to the interior of St. Peter's, that the stranger can be convinced of its prodigious extent in all directions. Comparisons are seldom pleasing, and not always just; it would therefore be, on many accounts, unfair to compare St. Paul's of London with St. Peter's of Rome. It must however be acknowledged, that the first view of the former has an effect very different from that produced by the latter; the chief cause of which is, that the nave of St. Paul's is really gloomy, and apparently narrow and low for its length; so that the spacious and lofty dome, instead of being only an accessory, becomes the principal part of the edifice.

The proportions and dimensions of rooms must be regulated by their uses. A dining-room, and a bed-chamber require very different proportions. A gallery for exercise in bad weather, especially if to be adorned with paintings and statues, must be of a great length in proportion to its height and breadth; which last must be governed by the necessity of possessing light from windows on one side only, to exhibit with due advantage the painting and sculpture ranged along the opposite side. A passage should be just wide enough to give a convenient communication between the several parts of the house: if it be wider we are offended with the waste of space, which the architect ought to have turned to some other use.

There is no part of a building in which the skill and taste of a builder can be better displayed than in the position and distribution of stairs. Even in the most spacious buildings a step may be made too broad, so as to require a sort of effort to move up or down from one to another. In spacious stairs the step should vary from 12 to 18 inches in breadth, and from 4 to 6 inches in height: the length varies also from 6 to 15 feet. Even in small houses, a step 8 or even 7 inches high is inconvenient; and the breadth should never be less than 9 inches, nor the length shorter than 3 feet.

Practical Architecture.

A competent knowledge of the methods of drawing on paper, and of working in stone, timber or other material, the several kinds or orders of columns, &c. is absolutely indispensable to enable the architect to discharge his duty to his employer, and the artisan to execute his commission.

It was already mentioned, that an order of architecture consists of three principal parts, namely, the column, its pedestal, and its entablature. Each of these parts is again subdivided into three parts, thus: the pedestal into its base or lowest member, the cubical body called from its figure the die or trunk, and the cornice above all. The column into the base the shaft and the capital. The entablature into the architrave, the frieze and the cornice. To give a competent explanation of the proportions and manner of constructing these several members, with the various ornaments appertaining to each, would require an extent and a number of engravings totally incompatible with the nature of the present work. But fortunately this particular explanation is by no means necessary: for the number of publications on this head is so great, that the student is more likely to be puzzled which to follow,

than to be at a loss for the want of a proper guide. Our observations must therefore be general and limited.

The simplest problem in mechanical architecture seems to be to determine the best form for a column. The length and the weight, (that is, the quantity of materials in the column) being given, it is of importance to investigate the form which affords the greatest possible strength: but it is somewhat difficult to ascertain the precise nature and direction of all the forces to be resisted which act upon the column. If a column were considered only as a beam fixed in the ground, and acted upon by a force pressing transversely or on one side, it ought to be much tapered, and reduced almost to a point at the upper end. But it is seldom that any force of this kind can be so powerful as to do more than overcome the weight of the column: the only thing therefore to be considered is the load which presses on it from above; hence whether we regard the force as tending to bend the column, or to crush it, the forms commonly employed appear sufficiently eligible. Some mathematicians have erroneously recommended the cylinder as the strongest form to resist bending; and in this opinion those who have not considered the subject are ready to join them; because a cylinder standing perpendicularly on one end, being of equal thickness, seems also to be of equal strength throughout. From the principles of mechanical philosophy, however, it can be shown, that the strongest form of an upright column approaches in fact much more nearly to that of an oblong spheroid or spindle, of which the outline is an arch of an ellipse. But the consideration of the flexure of a column is of the less practical importance in architecture, that, upon a rough estimate of the properties of the materials usually employed, a column of stone, (in order to be capable of being bent by any weight which will not crush it,) must be at least forty times as high as it is thick; although a bar of wood or of iron may be bent by a superincumbent load, if its length exceed about twelve times its thickness. But as even in the Composite order, the tallest and most delicate of all, the height of the column is only at the most ten times the thickness at the base, the action of the incumbent weight, in bending the column, ceases to be an object of much consideration. It is only then as a crushing force that the weight requires to be estimated; and since the lower parts of the column itself have not only the weight above, but its own upper parts to support, the thickness below ought to be somewhat increased. It appears by experience of the direction in which the fracture of a column is made, when crushed by too great a weight, that the outline ought to be made a little convex, or to swell a little on the outside of a straight line joining the extremities of the shaft, and more curved above than below; this is the usual but not the universal practice. An elliptic arch is perhaps the most eligible outline, or a curve formed by bending a ruler fixed at the summit of the column.

It is very natural in forming a column to copy the working of nature in forming the trunk of a tree, which may be considered, in a general sense, as a portion of a tapering cone, inclosed by straight lines joining the top and the bottom. But independent of other considerations it is to be remembered, that the great load of the boughs, branches, and leaves, act upon the trunk of the tree very differently from the load usually to be borne by a column.

A light-house placed upon a rock in the sea, may be considered

as a column erected, not to support a weight, but to withstand the action of wind and water. If we calculated what would be the best form for a wooden pillar, intended to remain always immersed to a certain depth in water, we should find that a cone or a pyramid would possess the greatest possible strength for resisting the motion of the water; and a cone still more acute than this would be equally capable of resisting the force of the wind, supposing it to be less powerful than that of the water. The part below the surface of the water might therefore be widened, so as to become a part of a more obtuse cone, the upper part remaining more slender. And the agitation of the sea being greatest at its surface, the basis of the pillar might be a little contracted, so as to have the outline of the lower part a little convex outwards, if the depth of the water were considerable. But in the case of a building of stone, the strength often depends as much on the weight as on the cohesion of the materials; and the lateral adhesion, which is materially influenced by the weight, constitutes a very important part of the strength. For resisting a force tending to overset the building, the form in which the weight gives the greatest strength is that of a conoid, that is, a solid of which the outline is a parabola, (a section of a cone parallel to its side,) concave towards the axis, and convex outwardly. And for procuring, by means of the weight, a lateral adhesion every where proportional to the force, the form must be cylindrical. Hence in a building such as this pillar is supposed to be, no reasons appear why either portion of its outline taken separately should be made convex towards the axis, although the joining of the two cones might very properly be rounded off. Of the form adopted for a building exposed to the violence of both water and wind, we have a remarkable example in the light-house erected on the Eddystone rock, situated in the entrance of Plymouth haven, about 14 miles out from the land. The top of the rock on which the light-house is founded is, it is true, constantly above the surface of the water, when the sea is calm; but in stormy weather every part of the building is exposed to the action of the waves, the water being often thrown up to a height far above that of the light-house; so that it may be considered as exposed to the force of a fluid acting more and more forcibly as it is nearer to the foundation. On this account the architect, the late ingenious Mr. Smeaton, chose for the walls a slope concave outwards, differing but little in form from that which the most accurate theory could have pointed out. The building however is probably a little weaker nearly as high as the middle of its height than in any other part. The light-house is wholly composed of cut stone, and about 16 feet in diameter at the bottom. The height of the building is 73 feet 6 inches from the rock to the top of the cornice; thence to the base of the lantern 7 feet 6 inches, and thence to the summit of the ball on the top 17 feet 6 inches; making the whole height 98 feet 6 inches. (See *Architecture*, Plate 3, Fig. 2.)

In diminishing their columns, various rules seem to have been practised by the ancient architects: sometimes the diminution began at the base, the shaft being formed by straight lines tending to a junction at a point beyond the summit of the column, by which measure the shaft became a frustum or portion of a very acute cone. In other instances we find the column carried up perfectly cylindric, or of the same diameter, for one-fourth, or more commonly for one-third of its height;

at which points the diminution begins, and extends to the capital. This junction, however, of the cylinder and the cone, although the angle formed by their outlines be almost imperceptible by the eye, appearing an imperfection, it was proposed and practised by eminent architects, to form the outline of the shaft by a curve running within the cylinder, but without the cone, from the base to the capital, in such a way, that the diameter of the shaft was, in every part, less than that at the base, but greater than that at the capital. The observations made on this point by Vitruvius, the great teacher of architectural mechanics, who flourished about the beginning of the Christian era, having in late times been misunderstood, it is no uncommon thing, in different parts of the continent, (to say nothing of our own country) to meet with columns, the outline of which consists of a curve actually swelling outwards, so that at one-third of their height their diameter considerably exceeds that at the base; a practice so offensive to the eye, as well as to reason, as to create wonder how it could ever be adopted by men who had ever seen, or even read of the monuments remaining of ancient architecture.

The different methods of giving to a column the proper diminution and most elegant sweeping outline, are particularly described in complete treatises on architecture. In this place we must content ourselves with giving the following plain instructions, by which every practical artisan may form his model and plan, with accuracy sufficient for ordinary occasions.

Let AB, fig. 1. plate 3. of *architecture* be the lower diameter of the shaft of the column to be drawn, and EF the upper diameter. On C, the centre of AB, describe the semicircle AGB, and erect the perpendicular CGD, which will represent the axis of the column. Through E, the extremity of the upper diameter, draw EH parallel to the axis DC, cutting the semicircle AGB in the point H. Now divide the arc AH into any number of equal parts, the more the better, as here, into 4, by the points marked 1, 2, 3. In the same way divide the axis into the same number of equal parts, as in the points marked *a, b, c;* through each of which draw indefinite right lines, at right angles, to CD. Through the points 1, 2, 3, of the arc AH, draw lines parallel to CD, producing them respectively until they meet the transverse lines drawn through *a b c* on the axis, in the points *d e f*, which will thus become points in the surface of the column. To assist in drawing these parallel perpendiculars, it will be convenient, through the points 1, 2, 3, in the arc AH, to draw 3*m*, 2*n*, 1*o*, to the axis parallel to the diameter AB; and setting off a distance equal to 1*o* upon the transverse line passing through *a;* another equal to 2*n* upon that passing through *b;* a third equal to 3 *m* upon that passing through *c;* the points *d, e, f,* will be obtained as before. Then setting on the transverses through *a* a distance equal to *a d,* through *b* a distance equal to *b e,* through *c,* a distance equal to *c f,* the opposite points *d e f,* on the other side of the axis, are also obtained. If now nails or pegs be fixed in the several points in the surface of the column thus ascertained, and along them, and the two extreme points of the upper and lower diameters AE and BF, a thin slip of timber, equally flexible in every part, be applied, it will shew the contour or section of the exterior of the column. The curve thus formed being carefully transferred, will mark the edge of the rule to be used in diminishing the shaft. In this process, it is evident, that

the more numerous the points of the surface ascertained, the more accurately will the slip of timber assume the proper form, and the diminishing scale be constructed. The two lines drawn from B to F shew the difference between the surface of the shaft, drawn in this way, and a right line joining the same points.

Mouldings. Although the shaft of a column do not admit of any ornament on its body, yet at each end, in the base and the capital, various ornamental parts are introduced, in the due distribution and proportion of which consists their principal beauty. These are, in general, called mouldings, because they are always of the same shape, as if they all proceeded from the same mould or form. Mouldings are by some writers divided into Grecian and Roman, with a reference to the remains of the architecture of those nations still in existence. The difference consists in this, that the Romans generally employed circular arches in their ornaments, while the Greeks often introduced parts of an ellipse, or of some other section of a cone varying from the circle. The principal parts of mouldings are these, 1st, The flat part under or above a moulding is a *fillet*, as resembling a bandage or ruban tied round the column. 2d, When the moulding projects in the form of a quadrant, or a smaller portion of a circle, it becomes an *echinus* or *Roman ovolo*, from its likeness to a portion of the shell of the sea-hedge-hog, or of a common egg. 3d, But if the moulding, reversing that figure, be a hollow of the same shape, it is therefore called a *cavetto*. 4th, A small projecting semicircular moulding is in general called a *bead*, as particularly belonging to the *astragal* or neck: But 5th, if the moulding be much larger, with a fillet above or below it, it then becomes a *torus*, as imitating a rope or cable applied to the column. 6th, If the section be a concave semicircle, or semiellipse, it becomes a *scotia*, because the interior is dark. 7th, When the projection is not properly a part of a circle, but rather of an ellipse, or of some other section of a cone, returning in quickly at the upper part, it is called a *Grecian ovolo*; and the quick return in it is by workmen called a *quirk*. 8th, A contour or section, partly concave and partly convex, is a *cymatium*, because it imitates the wave of the sea. 9th, If the concave part be uppermost, it is a *cyma recta*; but if the convex part be uppermost, it is a *cyma reversa*, or *ogee*.

Volute. It is impossible, within the narrow limits of this work, to go fully into the method of drawing all the variety of mouldings, foliage, or other ornaments of columns and their appendages; it must, therefore, be sufficient at present to shew one way of drawing the ornament called a volute, first introduced into the Ionic order, and afterwards adopted into the Composite. This method is neither the most simple, nor that which best accords with the purest remains of ancient art; it is, however, recommended by some late writers on architecture, and on this account it is now exhibited. Let the line AB (fig 1. of plate 4), be made equal to the perpendicular altitude of the intended volute, and be divided into 7 equal parts. On a perpendicular line of the same length, set up from the bottom three of these parts, which will determine the centre of the volute. But to show distinctly the manner of determining the several points from which the volute is described, the reader is referred to fig 2, of the same plate. About C, with one half of a seventh part of the given line AB, for radius, describe the circle DEFG, and draw the horizontal and perpendicular diameters EG and DF, by joining the extremities of which will be formed the square DEFG. From the middle

of the several sides of this square, if lines be drawn, another square 1 2 *m n* will be formed. From the centre C draw the diagonals C 1, C 2, and divide each into 3 equal parts, as in 9 5, and 10 6. Divide C 10 into 2 equal parts in the point *x*, from which let fall a perpendicular cutting EG in *z*, and *m n*, the lower side of the inner square in H. Producing *m n*, make HI and HK each equal to the half of *m n*. Then from *z* draw *z* K and *z* I, which will be parallel to the diagonals 1 2, *m n*, and draw the lines 5 4, 9 8, 6 7, 10 11, parallel to the perpendicular sides of the square; and if the horizontal line 11 12, be drawn, the central points 1, 2, 3—12, will be determined. From *o*, the middle of 1 *n*, (fig 1), set up the remaining 4 parts of the line AB to L, which will be the highest point of the volute or spiral, and from 1, as a centre, with the radius 1 L describe the quadrant LM. Then moving the compasses to the point 2 of the square, with the radius 2 M, describe another quadrant MN. Again, from 3, with 3 N for radius, describe NO. In the same way, from 4 draw O P, from 5 draw PQ, &c. continuing the operation until the volute be terminated by coinciding with the original circle in the middle, which is called the eye of the volute. In this way is the exterior line of the fillet of the volute obtained. The interior line, however, does not run parallel to the former, but in such a way, that the breadth of the fillet gradually diminishes until it in a manner vanish at the centre: the inner line is therefore drawn in this way. Having fixed on the breadth of the fillet at the beginning, as L *l*, divide it into 12 equal parts, corresponding to the several quadrants of the volute, (see fig. 3). From *x* set off 12 equal parts of any size; make 12 *y* equal to L *l*; join *y x*, and draw the lines *a* 11, *b* 10, *c* 9, &c. all parallel to *y* 12; then these cross lines gradually diminishing will be the several breadths of the fillet, at the beginning of each quadrant of the volute.

Drawing a column. In drawing or constructing a column of any particular order, the several dimensions and members are measured by a proportional scale, founded on the diameter of the lower extremity of the shaft, immediately above the projection at the base, where the shaft becomes rectilineal. This diameter is divided into two equal parts, each being the radius of the transverse section of the column, and is termed a *module.* The whole diameter is subdivided into sixty equal parts or *minutes,* of which, consequently, thirty are contained in a module. These proportional quantities are easily converted into real, when the lower diameter of the column is given in measure. Thus, if the lower diameter of a Doric column be 5 feet, or 60 inches, the module must be $2\frac{1}{2}$ feet, or 30 inches, and each minute will be 1 inch: and the Doric column being in height 8 diameters, the height of the given column will be 40 feet; hence, the entablature being one-fourth of the height of the column, its height in this case will be 10 feet, and so on.

In the Tuscan order, (supposing it to be complete), the height of the column is 7 times the lower diameter, or 14 modules; the entablature one-fourth of the column, and the pedestal one-fifth of the height of all the parts. Hence, let the whole height of a Tuscan column, with its pedestal and entablature, be fixed to 40 feet, the pedestal, being one-fifth of the whole, will be 8 feet high: The remaining 32 feet, divided by 5, will give nearly 6 feet 5 inches for the entablature, and 25 feet 7 inches for the column, of which the lower diameter being one-seventh, will be nearly 3 feet 8 inches. Had the order been Ionic, the

whole height, 40 feet, divided as before by 5, (for in all the orders the pedestal is always one-fifth of the entire height) would have given 8 feet for the pedestal, and the remaining 32 feet, divided by 6, would have given 5 feet 4 inches for the entablature, leaving 25 feet 8 inches for the column, of which the ninth part, or 2 feet $11\frac{1}{2}$ inches, is the lower diameter. But in general, when the whole height of the column, with its pedestal and entablature, is given, the several portions are thus found in all the orders. For the *Tuscan*, divide the entire height by 5, the quotient is the pedestal, and the remaining height divided by 5, will give the entablature. The remainder, divided by 7, gives the lower diameter of the column. *Doric:* divide the whole height by 5 for the pedestal; one-fifth of the remainder is the entablature; the rest is the column, of which the eighth part is its diameter. *Ionic:* Deducting from the entire height one-fifth for the pedestal, one-sixth of the remaining height is the entablature, and one-ninth of the remainder is the diameter of the column. *Corinthian:* After cutting off the pedestal as before, the entablature is one-sixth of the remainder, as in the Ionic; and one-tenth of the rest is the diameter of the column. For the *Composite* order the same proportions are employed. By inspection of the plates on architecture herewith given, the perpendicular height and horizontal projection of the members and their various parts will be sufficiently understood. In laying down any order on paper, draw a perpendicular right line to represent the axis of the column. Near the bottom draw another line horizontally at right angles, on which, from the perpendicular, set off on each side, a distance equal to a module, or one half of the diameter. On a separate line, equal to this diameter, form a scale of 60 equal parts, or minutes, by which to measure all the dimensions, reducing them to minutes from the number of feet and inches in which they are usually given. The construction of such scales is, however, generally unnecessary, from the variety to be found on Gunter's and other scales of wood, brass, &c. sold by the makers of mathematical instruments. On the axis of the column produced below it, set off progressively downwards from the bottom of the column, the heights of the several members composing the base and pedestal; and through each of those points draw pencil lines at right angles to the axis. Again, from the same bottom line of the column set up along the axis the several heights of the capital, architrave, frieze, and cornice, drawing, as before, lines at right angles through each point thus ascertained. Then from the axis set off on each horizontal line, the proper projection of all the several parts in order; by which means the true elevation and projection of each will be obtained. The extremities of these horizontal lines are then connected by the fillet, the ovolo, the cyma recta, &c. according to the kind of ornamental profile belonging to each particular order of architecture. It was formerly observed, that no Tuscan entablature, certainly antique, now exists: as, however, modern architects, following Palladio, Scamozzi, and others, have taken upon them to complete the Tuscan order, of which the column alone is known, a profile of Palladio's scheme is given in the plate.

Although the relative proportions of the various parts of the orders be generally marked on the plates, it will still be of service here to give a brief account of some of the principal parts of each.

Tuscan: In this order the height of the column is 7 diameters, or 14 modules; that of the whole entablature $3\frac{1}{2}$ modules, subdivided into 10

equal parts, of which 3 are for the architrave, 3 for the frieze, and 4 for the cornice. The height of the capital is 1 module, the base, including the lower cincture (peculiar to this order) of the shaft, is also 1 module; and the shaft, with its upper cincture and astragal, is 12 modules. When this order is employed within doors, the column may be enlarged to $14\frac{1}{2}$, or even 15 modules; the other parts remaining as before. It is customary to diminish this column one-fourth; but no reason can be given why the diminution should exceed one-sixth, or one-eighth. *Doric:* The height of this column has greatly varied, at different epochs, from 4 to eight diameters, which last proportion is usually employed by the moderns, or 16 modules, including base and capital; in which case, the entablature contains 4 modules. This space, subdivided into 8 equal parts, allots 2 for the architrave, 3 for the frieze, and 3 for the cornice; the base is 1 module in height; the capital somewhat higher or 32 minutes. *Ionic:* Height of the column 18 modules, of the entablature $4\frac{1}{2}$, capital 21 minutes, and base 30: the shaft, either plain or fluted, with 20 or 24 flutings: the fillet betweeen them never broader than one-third, nor narrower than one-fourth of the flute. The entablature being divided into 10 equal parts, 3 are for the architrave, 3 for the frieze, and 4 for the cornice. For the illustration of the Ionic order, the reader is presented with a plate representing the frontispiece and portico of an antique temple in Rome, universally esteemed by the best judges as the most regular, correct, and elegant specimen of this order now in existence. This is the temple of Manly Fortune, still in such preservation, as to be converted into the church of St. Mary the Egyptian. The edifice is a parallelogram, elevated above the ground, and approached by a stair extending the whole length of the portico, consisting of 4 fluted columns. Opposite to the middle intercolumniation is the door of the temple, which, in the plate, appears as if connected with the columns; because, had the figure been shaded, so as to show the retreat of the wall and door, the due proportions of the whole frontispiece could not have been distinctly exhibited. *Corinthian:* This order differs from the Ionic chiefly in the capital, which occupies 1 whole diameter, while the Ionic capital takes up only one-third of a diameter. The moderns adopt the following proportions: the column 20 modules, the entablature 5, the base 1, the capital $1\frac{1}{6}$; the proportions of the members of the entablature the same as in the Ionic. When the entablature is enriched, the shaft of the column is fluted, the flutings being filled up with a rod or cabling to one-third of their height, which actually strengthens, while it does not diminish the beauty of the column. The capital is enriched with olive leaves, in imitation of most of the ancient vestiges now remaining; the acanthus, notwithstanding the story of the origin of the Corinthian capital seeming to have been but seldom introduced. *Composite:* Height of the column 20 modules, of the entablature 5, of the capital $1\frac{1}{6}$, the base as in the Ionic; the shaft may also be fluted, as in the Ionic, with 20 or 24 flutings; the entablature divided into 10 equal parts, of which 3 for the architrave, 3 for the frieze, and 4 for the cornice. A specimen of the Composite order, singularly rich and beautiful, exists in Rome, in the triumphal arch erected to commemorate the awful and predicted destruction brought upon the city and temple of Jerusalem by the Romans, in the year 70, under Titus, during the reign of his father Vespasian. Under the arch are sculptured the golden candelabrum of seven branches,

the table of shew-bread, and other spoils carried away from the temple It is the ingenious, and not improbable fancy, of some eminent writers on architecture, that the general idea of the Composite order, as it appears in the arch of Titus, was borrowed by some Roman artist in the suite of that general from the structure of the temple of Jerusalem itself, after the conquest of the city, but before its utter overthrow. Josephus, it is true, says the columns of the temple were Corinthian; but the differences between that order and the Composite might not attract his attention, nor would they have been generally deserving of notice. At any rate, the triumphal and tropheal arch of Titus is the most ancient monument in which the Composite order is discovered. This arch possesses another peculiarity, that it is supposed to be the *first* structure of the tropheal or triumphal kind erected by the Romans; an example soon afterwards imitated by the abject adulation of the people, or rather by the insulting vanity of their princes; until at last, such trophies being lavished without discrimination, ceased to be marks of honourable distinction.

The feelings and duties of human beings in a social state of existence naturally spring from that state. To a person brought up from infancy in absolute solitude, such feelings would only produce misery, and such duties would be a nonentity. Let, however, two persons be placed in mutual communication, and that instant feelings of kindness or dislike, of affection or hatred, will arise. Let both be hungry, and that one apple or one orange only be to be procured, this each will instinctively desire to appropriate to himself; for an equal distribution of the object of their desires between them must be the result of posterior experience and reflection, and not the spontaneous suggestion of the occasion. Is the one a little stronger or more alert than the other, he will avail himself of these advantages over his fellow-being to seize the object of his wishes. By this sole appropriation, the other sustains, not an imaginary, but a real loss. The natural desire for necessary aliment will aggravate his feelings of disappointment and defeat, into aversion, resentment, and vengeance, against his spoiler; and should he be frequently thwarted in a similar way by his companion, nothing short of the entire destruction of that companion will appear sufficient to secure himself from future privations and sufferings. This process will take place in the breast of the weaker being, even although the stronger should not attempt to assume to himself still greater advantages, in consequence of his acknowledged superiority. That the latter will, however, be governed by sentiments so moderate, is extremely improbable. The self-gratulation arising from consciousness of power, will yield a pleasure too delicious not to induce the desire of again experiencing such delight. He will thus naturally be disposed to exercise his superior faculties, not when the calls of necessity only, but when the suggestions of vanity or caprice may furnish opportunity. Hence, his feebler neighbour will by degrees be reduced to absolute slavery, dependent on the other for even the necessary means of existence; and of this existence itself, should he long continue refractory, he will probably be at last deprived. Thus may be traced the origin of the worst feelings and actions by which human beings are distinguished; and by a similar but opposite process may the rise and progress of the best sentiments and conduct be explained. In absolute sequestration and solitude, neither virtue nor vice can exist: but without virtue and vice in society, human beings can

have no existence. When this simple and obvious theory of what is called the origin of evil, (a theory by far too simple and too obvious to have fixed the attention of presumptuous philosophy in any period of the world,) is considered, it will excite no surprise, that the history of mankind, under even the most favourable circumstances, should present little else than an endless chain of deplorable wickedness and wretchedness, equally the natural consequences of folly and of vice. "We are a contemptible gang of plunderers, pests of society, meriting, forsooth, punishment the most severe and disgraceful, because we appropriate to ourselves the property of unoffending men, and even, on some occasions, deprive the owners of life; and all this we do, few in number, more frequently by secret stratagem than by open force, and even in some measure authorised by the sanction of necessity. Thou, on the other hand, born to independence, to wealth, to power, to supreme dominion, without even a rival to attempt to obstruct the gratification of thy desires; without provocation, without invitation, without necessity, without any motive or reason, which a man of genuine courage and truth, a friend to human kind, would avow;—thou destroyest cities, the abode of industry, knowledge, and patriotism; thou layest waste peaceable and flourishing countries where thou hast received no injury; thou causest to flow torrents of the blood of nations who never even heard of thy name: and all this thou dost at the head of armed myriads, in open defiance of common justice and humanity; therefore art thou exalted to the rank of a hero, a conqueror of worlds, a demigod." In such a strain, we are told, was the mighty Alexander of Macedon addressed by the petty chief of a band of pirates who fell into his hands, and whom he conceived himself authorised to punish, in an exemplary manner, for their outrages on society; and the observations are fully warranted by the undeviating practice of all people, and of all times. Hence, we find in the most ancient records of human society, applause and reward lavishly bestowed on the successful warrior, whether just or unjust the cause in which he was engaged. But besides these and other marks of the real or supposed admiration and gratitude of their armies and people, conquerors were in the habit of constructing some more substantial evidence of their victories, on the scene of their exploits. At one time a rude block of stone, at another a mound or hillock of stones and earth, raised on the field of battle, served at once to point out the spot where the honours of the victor were achieved, and where rested from their toils the human beings prematurely cut off, in the performance of the duties he imposed. Of such monuments many examples still survive the long lapse of ages, in our own country, in Cornwall in Wales and in Scotland. These dumb memorials came at last into disrepute: they recorded, indeed, a slaughter and a victory; but succeeding generations, when tradition grew feeble, or entirely died away, were left to conjecture the cause of their erection; and the mighty warrior was thus bereft of half his glory. When the Romans began to establish themselves in the southern parts of Gaul, and to extend the boundaries of their province, now Provence, Languedoc, and Dauphiny in France, they first constructed durable memorials of the success usually accompanying the exertions of united and well-disciplined bands, although far from numerous, against countless multitudes of irregular, ungovernable barbarians. Two Roman generals, Domitius Ænobarbus and Fabius Maximus, erected on the banks of the Rhone, *saxeæ turres*, towers built of stone, supporting

trophies, consisting of arms offensive and defensive, standards, instruments of martial music, and other pledges of victory, taken from the vanquished Gauls. This conduct on the part of their commanders was highly reproved at Rome; for until then the Romans had never allowed themselves, even after their most signal success in war, to erect in the midst of a conquered people any monument whatever, by which they should be reminded of their subjection, and be consequently excited to endeavour to regain their former independence:—"Never before this," says the historian, "did the Roman people upbraid any conquered nation with their own defeat." This happened about 120 years before our era. Some time afterwards, Pompey constructed on the summit of the Pyrenees, near their eastern extremity, a permanent building, as a memorial of his successes, slight enough indeed, over partial but patriotic attempts of the Spaniards to throw off the Roman yoke. This action was also severely reprobated at Rome. The same magnanimous sentiment actuated not the free states of Greece only, but even the despotic and military kingdom of Macedon. "States and nations," said those ancients, "like individuals and families, will differ upon particular points, where their interests, real or supposed, are concerned. These differences will lead to quarrels, and even to the most hostile proceedings and open warfare. It is not unnatural that, in these contests in arms, the victors should endeavour to confirm the courage and ardour of their own people, and to depress the spirit of their adversaries, by some public testimony of their superiority. For such a purpose, a few helmets, and breastplates, and shields, and swords, taken from the vanquished, and supported against a spear, or suspended on a tree, on the scene of victory, will be fully sufficient. Let not, however, such emblems of superiority be of long duration. The passions of men will cool, their views of interest will change, and the parties which to-day meet with deadly rancour in the field, will be found in a short time united in one common cause, and fighting, as friends and brothers, against an ally of one of the parties on a former occasion, but now become a common foe. It is, besides, to be considered, that success in war is not always attached to one side: no nation was ever always victorious, nor always discomfited. Let us never, therefore, by *permanent* records of our *temporary* superiority, labour to cherish and foment among our neighbours that spirit of hostility, which, at no distant day, it may be equally our desire and our interest entirely to extinguish. Injuries men often will and do forgive; insults, perhaps, never." Such were the wise and magnanimous sentiments and principles of the Greeks and Romans, the two most enlightened nations of antiquity, in their best days. In the degenerate days of Titus and Vespasian, however, when Rome reigned paramount over the greater portion of the civilised world, the feeling of national importance and independence, the source and support of every manly, generous, and patriotic principle, was next to extinct in the nations of Europe. The example set in the case of Titus, was speedily followed; and not only Rome itself, but numbers of the principal cities over the empire were adorned with edifices, triumphal, tropheal, and commemoratory, many of which still remain, exhibiting admirable specimens of architecture and sculpture; and by the inscriptions and representations with which they are charged, serving to illustrate and establish the dates of many important historical facts. Wisdom, justice, and moderation, are immutable; and as such, never (let weak, and consequently narrow-

minded men say what they may,) can be inexpedient or out of season. Human nature is at this day what it was twenty centuries ago. Let then the prudence and humanity by which states were then governed, and not the overbearing presumption and insolence on the one hand, and the abject interested adulation on the other, by which later periods have often been characterised, suggest the most commendable models for modern imitation.—But to return to the arch of Titus: it may just be added, that the unfortunate branches of the Hebrew nation established in Rome, made an arrangement, many years ago, with the government, agreeably to which, for the payment of a certain sum of money, they were permitted to open a narrow passage by the side of that arch, which, although not now connected with the inhabited part of the town, is situated in the heart of the old city, on a very public thoroughfare; that their minds might not be tortured unnecessarily by the display of the emblems of the final destruction and extinction of their religion and their state, of their name and their nation. This digression, the reader will, it is trusted, without difficulty pardon. It arose naturally from the subject, and may, perhaps, suggest certain considerations not unprofitable at the present conjuncture.

With respect to the kind and degree of ornament to be introduced into a column and its appendages, it is a maxim founded in our natural sentiment of what is decorous and beautiful, that if we are in doubt concerning the proper medium, we should always stop short of the supposed point, and be careful never to go beyond it. The pupil of an ancient painter of Greece produced a Venus loaded with jewels. "Unable to make the goddess beautiful," said his master, "you have thought to atone for that defect by making her rich and fine." The dignified sobriety and gravity becoming an edifice appropriated to religious purposes, or to the senatorial and legislative assemblies of a great and an enlightened people, the massive solidity and strength inherent in our idea of a fortress, the light, airy, exhilarating notion attached to the name of a theatre, or other place of amusement; all these qualifications of the edifices to be constructed, will, to an architect of genius, suggest the species and the measure of the ornament suitable to each. A slender, delicate, and highly enriched Corinthian portico to Newgate prison, could not be more incongruous, nor indicate a greater want of taste in the builder, than a massive, heavy, clumsy Doric (if Doric it be), range of pillars, and their pediments corresponding, apparently forbidding, but, doubtless, meaning to invite the passing stranger to enter the theatre of Covent Garden. When we examine the monuments remaining from antiquity, we find that the cyma, the cavetto, or other ornament formed by cutting into the substance of the work, is employed as a finishing only, and never where strength is required: that the ovolo and talon are employed to support the essential parts of the entablature, such as the modillions, dentiles, and corona: that the principal use of the torus and astragal is to secure and strengthen the extremities of the columns; being also employed for the same purpose in pedestals, carved so as to resemble a rope or cable, agreeably to the original signification of the term torus; that the scotia serves merely to separate the members of the base, as does also the fillet, not only in the base but in profiles of all kinds. By the term profile is here meant the assemblage of parts, mouldings, and ornaments of a cornice, &c. in which the elevation and projection of each member are exhibited. The most perfect profiles are

those consisting of the fewest mouldings adapted to the order of the column, so disposed that the rightlined and the curved members succeed one another alternately. In every profile one member should be predominant, to which all the others must appear subordinate; thus, in a cornice, the corona is the chief member, the cyma or the cavetto covers and defends it from the rain, while the modillions, dentiles, ovolo, and talon, serve to support it. In the arrangement of the exterior of a building, whatever does not directly tend to characterise its destination, however beautiful in itself, is always misplaced. Greatness of character in an edifice is principally produced by largeness and simplicity of parts: such parts, not only by their own magnitude, but by the great masses of light and shade they exhibit, when fully illuminated, excite the idea of grandeur. An object may be great without being grand; but grandeur and smallness of parts are wholly incompatible. One of the most extensive edifices in Europe is the king of Spain's palace at the Escurial, not far from Madrid. It covers a vast extent of ground, inclosing a number of courts, porticos, chapels, &c. in its bosom. Having, however, been constructed as a monastery rather than as a palace, (for the royal apartments are confined to a very small portion of the structure) the building is divided into various floors, and consequently the exterior walls are pierced with various ranges of comparatively small windows adapted to the cells and halls of the monks. The consequence of all this is, that the idea of grandeur and magnificence raised in the mind of the spectator, while approaching it from a distance, and observing its prodigious dimensions, entirely vanishes away, when, on a closer view, the whole is discovered to be only an assemblage of small diminutive parts and members, such as might be suitably introduced into a manufactory, a barrack, an hospital, or a convent. Many objections have been made to Blenheim palace, in Oxfordshire, as clumsy, ponderous, inelegant, and by no means corresponding to the customary notion of a country residence. That magnificent edifice was erected at the expence of the nation, to commemorate the signal victory obtained in 1704, near Blenheim, a village on the north bank of the Danube, by the allied army, under the duke of Marlborough. That distinguished and modest commander stands, next to Julius Cæsar, unrivalled in history for perfect coolness and possession of himself in action; who, so far from ever exposing himself to the possibility of being surprised, whatever might have been the talents of his opponent, never rested until he was so close upon the enemy, as, in many cases, to disconcert their measures, and prevent their forming any project against himself, for the greater part of a campaign. Like Cæsar also, in person a hero, he was scrupulously tender of the lives of his men, and to spare them, would often forego the opportunity of a brilliant, but sanguinary and useless victory, for the more slow, but more secure, and infinitely more difficult advantages to be obtained by skilful occupation of ground. On a due consideration of the destination of Blenheim, it will be manifest that the architect, Sir John Vanburgh, intended, by throwing the structure into a variety of large projecting and retiring masses of building, to produce broad and powerful effects of light and shade; and by that contrivance to fill the spectator with an idea of the vast magnitude of the parts, and of the whole, far beyond what their real magnitude, considerable as it is, could be expected to excite.

Caryatides. Besides regular columns and pilasters we sometimes

meet, in ancient and in modern architecture, entablatures supported by human figures. These are termed Caryatides from the following circumstance: Five hundred years before our era, Xerxes, the powerful monarch of Persia, led a prodigious army and fleet against the free and independent republics of Greece. Successful at first, more by treachery than valour, he was at last discomfited at every point, and compelled to return with disgrace and ruin to his own country. Carya, a town of Peloponesus, had basely formed a league with the invader; and upon his flight it was besieged by the other states, levelled to the ground, the male inhabitants put to the sword, and the unhappy, perhaps innocent females reduced to slavery of the severest kind. To perpetuate to future ages the infamy and the punishment of the people of Carya, in Athens and in many other parts of Greece, buildings were erected, in which were introduced, in the place of columns and pilasters, figures of Caryan women, supporting the load of a cornice and entablature. In general these figures are attached like pilasters to the wall; but in Athens they are also found detached, and performing the duty of columns. Male figures are also employed in the same way in some ancient buildings in Greece and in Rome; in Greece they are evidently intended to represent Persian prisoners taken from Xerxes. From this account it is evident that human figures, in the place of columns or pilasters, ought, if at all, to be introduced on very particular occasions indeed. They nevertheless are often seen in the palaces of princes, and even in private dwellings. Our churches themselves, in which all adventitious distinctions among mankind ought, if any where, to disappear, are not free from this absurdity. These poor females, humiliated, borne down with a heavy load, are meant, we are to understand, for the muses and the graces, the virtues and the angels themselves. Could the vices which corrupt, and the furies which torment the human race be thus chained down, and so rendered in some sort subservient to our use, such an application of Persians and Caryatides might easily be reconciled to reason. A party of angelic figures have lately taken post on the top of the new steeple of the new church in the new road in Mary-le-bourne. To vulgar eyes they seem to be placed there for no other purpose than to support the crown of the edifice. As, however, their countenances are severally directed, to every point of the compass, they may perform the duty of sentinels to guard the church from all external assault: internal danger is beyond their ken. Not only entire human figures, but simple busts are also employed occasionally, to support the entablatures of monuments, chimney-pieces, &c. The head is placed on a stand smaller below than above; and the whole is called a *term*, from *terminus*, a boundary, the Roman name of the land-marks, or march-stones, erected round fields and possessions, to point out the boundaries between the lands of different proprietors. The protecting charge of these land-marks, as of every thing else connected with the affairs of industry and commerce, being entrusted to Mercury, by the Romans as well as by the Greeks, the top of the stone or post was carved in resemblance of his head; so that to destroy, or remove, or deface such monuments, was wisely regarded, not only as a gross injustice to men, but as a voluntary and impious offence against the powers above.

It now remains to give a few observations on the construction of *bridges*, one of the most important and difficult applications of architectural skill.

Bridges.—By a bridge we mean a structure of stone, brick, timber, or iron, erected over a river, a canal, a valley, or other depression in the ground; and supported on piers and arches, or on posts; for opening a communication for passengers cattle and carriages, across from the one side to the other. The perfection of a bridge consists in its having a good foundation that it may be durable, an easy ascent and descent that it may be convenient, and a just proportion in its several parts that it may be beautiful. Bridges should always be placed at right angles to the course of the river, &c. and the piers should never be thicker than is just necessary to support the structure against the force of the current.

The simplest theory of the arch, supporting itself in equilibrium (that is, in such a state that the tendency of every part to fall down or give way is perfectly equal), is that of Dr. Hooke, the greatest of all philosophical mechanics, who flourished in the latter part of the seventeenth century. The arch, when it has only its own weight to bear, may be considered as the reverse of a chain suspended freely at each end; for the chain hangs in such a form that the weight of each link is held in equilibrium, by the result of the two forces acting at its extremities; and these forces or tensions are produced, the one by the weight of the portion of the chain below any particular link, the other by the same weight increased by that of the link, both of them acting originally in a vertical direction. Now supposing the chain inverted so as to constitute an arch of the same form and weight, the relative situations of all the lines, indicating the directions of the forces, will remain the same, the forces acting only in contrary directions; so that they are compounded in a similar manner, and balance each other on the same conditions, but with this difference, that the equilibrium of the chain is stable, and that of the arch is tottering. When the links are supposed to be infinitely small, and the curvature of the chain is greatest in the middle, the chain forms what is called the catenarian curve, from *catena* a chain. In common cases this form of an arch differs but little from a circular arch of about 120°, or one-third of a whole circle, arising from the abutments with an inclination of 30° to the perpendicular: the arch however becomes more curved at some distance below the summit, and then again less curved.

The supposition however of an arch resisting a weight acting only in a vertical direction is by no means perfectly applicable to cases usually occurring in practice. The pressure of loose stones and earth, moistened as they generally must be by rain, is exerted very nearly in the same manner as the pressure of fluids, which act equally in all directions: and even if the stones and earth were united into a solid mass, they would constitute a sort of wedge, and produce a pressure of a similar nature.

A bridge must also be so calculated as to support itself, without being in danger of falling by the defect of the lateral adhesion of its parts. In order that it may, in this respect, be of equal strength throughout, the depth at each point must be proportional to the weight of the parts beyond it. This property belongs to the logarithmic curve alone, the length being made to correspond with the logarithm of the depth. But in the construction of bridges it is necessary to inquire what is the best form for supporting any weight which may occasionally be placed on the bridge, in particular on its weakest part, which is usually the mid-

dle of the arch. Supposing the depth at the summit of the arch and at the abutments to be given, it may be considerably reduced in the intermediate parts, without impairing the strength; and whether the road along the bridge be horizontal or a little inclined, it is agreed that an elliptic arch, not differing much from a circular, is the best calculated for complying as much as possible with all necessary conditions.

The tier of bricks cut obliquely, which is usually placed over a door or a window, is a real arch, but so flat as to allow the outline to appear horizontal. Little dependence however can be placed on so flat an arch, since it produces a lateral thrust that might easily overpower the resistance of a side wall. For the horizontal force required to support each end of an arch is always equal to the weight of a quantity of the materials supported by its summit, supposed to be continued of their actual depth, to the length of the radius of the circle, of which the summit of the arch is a portion. This simple calculation will enable an architect to avoid such accidents as but too often happen to bridges, for want of sufficient firmness in the abutments. Very eminent modern architects have sometimes been less successful in constructing arches of bridges and other edifices than those of former times, whom it is but too common to despise; and for want of attention to mechanic principles they have committed such errors in their attempts to procure an equilibrium, as have been followed by the most mischievous consequences. Examples of this mismanagement might be pointed out in the bridges of our own country, and the churches of others: but if we are masters of the true nature and action of pressure we shall be able to avoid similar errors, unless some defect in the materials, the foundation, &c. occur which could not be foreseen.

It is desirable that the piers of bridges should be so firm as to be able, not only to support the weight of half of each adjoining arch, but also to sustain the side-thrust of one of them, should the other give way. The same condition is necessary for the stability of walls of any kind, employed in supporting an arched or vaulted roof: hence the utility of the external buttresses which strengthen and adorn Gothic structures. There are two ways in which a pier or a wall may give way, it may either be overset or caused to slide away horizontally. But since the friction or adhesion which resists the side motion is usually greater than one-third of the pressure, it seldom happens that the whole thrust of the arch is so oblique as not to produce a sufficient vertical pressure, for securing the stability in this respect: and it is only necessary to make the pier heavy enough to resist the force which tends to overset it. It is not however the weight of the pier only, but that of the half of the arch which rests on it, that resists every effort to overset it; and in order that the pier may stand, the sum of these weights, acting on the end of a lever, equal to half the thickness of the pier, must be more than equivalent to the horizontal thrust, acting on the whole height of the pier. The pier may also be considered simply as forming a continuation of the arch; and the stability will be preserved as long as the curve, indicating the direction of the pressure, remains within its substance. The dimensions of the piers must depend on the size and form of the arch, as also on the force of the current to be opposed. In tide rivers such as the Thames, the current acts twice a day in contrary directions, rising considerably above the surface of the river itself, and re-

turning to that level. The pressure on the piers is therefore very unequal; and from the circumstance that the stones must be thus in a continual alternation between wet and dry, the selection and placing of the materials becomes a matter of the greatest importance. Some persons are of opinion that blocks of stone resist the action of water and sun, of wet and dry weather best when placed exactly in the same position as when they lay in the quarry. Whether this circumstance, if real, was attended to or not, in the construction of Blackfriars bridge in London; or whether the stone was of an improper kind; it is certain that such parts of the piers as are exposed to be covered by the tide are now in a state of manifest decay; while the corresponding parts of Westminster bridge are comparatively but little affected; although it was founded in 1738, and the former bridge not till 1760. The new Strand bridge is built of granite, the least subject to decay of all stone from external causes. The stone lately employed in constructing the grand quay along the front of the arsenal of Woolwich is drawn from the vicinity of Dundee in Scotland, and is found to answer much better in such a situation where it is alternately with short intervals wet and dry, than any formerly employed. It has been likewise used in some of the great basons and docks in London, and in constructing the piers to support the iron bridge over the Thames at Vauxhall.

In building a bridge the most essential part of the enterprize is to secure a good foundation. The most simple method of doing this, and carrying up the piers to the ordinary height of the water, is to turn the river out of its course, above the position of the bridge, into a new channel opened for it, near the place where it makes an elbow or bend; or by raising an inclosure round the spot where the pier is to be built, to keep out the water, by driving a double row of stakes into the bed of the river, very near one another, with their tops above the surface of the water. Hurdles are then put within this double row of stakes, the side of the row which is next to the intended pier is closed up, and the hollow between the rows filled with rushes and mud, so closely rammed down that water will not pass through. The mud, sand, stones, &c. within this inclosure are then dug out, until a solid foundation appear: when such a foundation cannot be found, one of wooden piles, having their lower ends well charred (See *chemistry*, p. 120.) to prevent their rotting, and driven into the bottom of the river as close together as possible, must be made. Some architects have formed a continued foundation the whole length of the bridge, and not merely under the piers. In doing this, first one part of the river is excluded, and then another, until the whole foundation be laid. When a river is but of moderate depth, having such a bed as may serve for a natural foundation, capable of bearing, without subsidence in whole or in part, a heavy pier, then a strong frame of oak is constructed and kept upon the surface by boats around it. On this frame is laid a thick stratum or layer of stone, cramped together by iron bars, and united by strong terras mortar; the whole of which being then specifically heavier than the water, is suffered gently to sink down to the bottom, on the spot where the pier is to stand. If it be required to construct a bridge across a fordable river or a canal, where the course of the water may be turned off, either by a wooden fence placed obliquely across the river, or by a channel dug on one side; then a dam must be formed entirely across the stream with piles, at a convenient distance above the place of the

intended bridge. The ground is then dug out until a proper solid foundation present itself; and all the piers may be founded and raised up to the usual height of the river, at the same time; after which the river is permitted to return to its original channel. When the stream is by far too considerable to be turned aside coffer-dams are formed, of a circular shape, to inclose the spot where each pier is to be built. The dam is made, as before said, by driving into the bed of the river a double row of stout piles, either charred at the lower end, when the bed is easily penetrable, or shod for several feet with iron, where it is hard. The piles are forced into the ground by repeated blows from the pile-engine: the piles are covered with boarding without and within, so as to be tolerably water-tight; and the water which does make its way through the walls, or which springs out of the inclosed bed, is drawn off by pumps and hand-labour, or, if the undertaking be considerable, by means of a steam engine.

Besides bridges other bodies of masonry are also requisite, if not completely to traverse, at least to advance a considerable way into water: such are the moles and piers carried out from the land into the sea, from opposite points of the shore, and mutually bending round towards each other at their extreme points, where they leave an interval sufficient for the passage of ships out or in. In our seas where we have the advantage of the retreat of the sea twice a day at low water, such structures can be founded and carried up in general without particular difficulty. In the Mediterranean however, where the rise and fall of the tide is either very unimportant or wholly insensible, as along the coasts of Spain, France, Italy, &c. the construction of a mole becomes an enterprize of vast labour and difficulty and expence. The work begins at the shore, by throwing into the sea blocks of rock or stone, the larger and ruder the more useful. These find their place in the bottom, and by accumulating block upon block over them at last they rise above the surface of the water. The work being so far advanced advantage is taken of the blocks above water to form a road, by which other blocks are carried out and rolled into the sea, beyond those already placed; and these again in their turn serve, when they come to the surface, to convey another succession of blocks, until the foundation of the mole be carried out to the intended extent. When we take into consideration the inequalities of the bottom of the sea, where not covered with hard sand; the incessant internal motion of the waters produced by currents, to say nothing of the superficial agitation produced by the winds; that most rocks and stones lose a great part of their weight, when immersed in salt water, and are consequently the more easily moved about from place to place by the motion of the waters; also the great extent in breadth to which rude blocks of stone or rock will necessarily roll, before they find a bed, either in the bottom of the sea, or upon one another:—when all these things are considered, the structure of moles and piers in such seas must appear to be an enterprise of extreme difficulty, and expence. In such seas however no other mode of constructing an artificial harbour can be devised. When the foundation is supposed to be sufficiently consolidated, and is raised above the surface of the water, the mole is completed by a structure of hewn stone, founded in the interstices of the sunk blocks, and adapted to the purposes of commercial and maritime affairs. Of this construction are the old and the new moles of Gibraltar, of Alicant, Tarragona, and Barce-

lona, in Spain; of Sette, and Toulon in France; of Genoa, Leghorn, Civita Vecchia, Naples, and Ancona in Italy, &c. The famous antique mole at Pozzuoli, in the bay of Naples, is constructed with piers and arches founded in the sea, and is from its appearance called Caligula's bridge, having been, as is supposed, erected by that imperial monster. On the same principles with the moles just described is constructed what is called the break-water, in the entrance of Plymouth haven; in the view of abating the violence of the waves and currents which have, on many occasions, proved most prejudicial to the fleets resorting to that otherwise admirable station for shipping of every sort. In the report laid before parliament concerning this prodigious enterprise, which is carried on at the public expence, the engineers Messrs Rennie and Whitby, (the former the engineer for the Strand bridge in London,) state that there are properly speaking three entrances into Plymouth Sound or Haven, viz. one on the west side of the bay, bounded by a long cluster of small rocks called Scot's Ground, on which the depth is only from three to four fathoms, (from 18 to 24 feet) at low water; and on the east by the Knap and Panther, on which is about the same depth of water. This channel is about 500 fathoms wide, and the general depth is from 5½ fathoms to 6, at low water. The middle channel is bounded by the Knap and Panther on the west, and by the Tinker and Shovel on the east; about 300 fathoms wide, and the general depth from 6½ to 8 fathoms at low water. From this description it appears that a large part of the middle of Plymouth Sound is shut up by the Shovel, and St. Carlos rocks, that is as a channel for large ships. Of course works erected on those rocks would be no obstruction to passage in or out of the sound. If a pier or break-water were constructed on the Shovel rocks and extended westward, so as to shut up in part the channel between them and the Panther, and also to shut up or narrow the spaces between St. Carlos rocks and Andurn point, the tide being then confined to a narrower space, the velocity of the current would be increased, and consequently the channels where it passed deepened. It seemed therefore proper that a pier or break-water, should be constructed in the sound, having its eastern end about 60 fathoms east from St. Carlos rocks, and its western end about 300 fathoms west from the Shovel, forming in the whole a length of 850 fathoms. Of this pier 500 fathoms in the middle should be straight, and 175 at each end inclined at an angle of 120 degrees. In addition to this break-water, another should be extended from Andurn point on the shore, towards the former, of about 400 fathoms in length, having also a part inclined at an equal angle. These inclined parts were to reflect the waves in such a manner as to prevent them from passing violently through the opening between the piers, and so shelter the Sound within, as to permit fifty sail of line of battle ships to ride at anchor in safety, in all winds and weather; and with ample room to work their way out to sea, by one or other of the channels, as their position and the state of the wind might render most convenient. These great works were to be constructed by large blocks of stone thrown at random into the sea, in the line of the intended break-water, to find their own bed. Stones from a ton and a half to two tons weight would probably resist the swell of the Sound, in stormy weather. Where the water is 5 fathoms deep, the base of the break-water should not be less than seven times that depth, or 70 yards in breadth, and 10 yards broad at a height of 10 feet above the level of

low water of ordinary spring tides. The slope of this foundation on the outer side next to the sea should be in the proportion of 3 yards horizontal, for 1 yard perpendicular; but the slope on the inside next the sound would require an inclination of only half that quantity, or $1\frac{1}{2}$ yard horizontal, for 1 yard perpendicular. To the project here described, and now far advanced towards completion, various objections were made, particularly by Mr. Bentham, who had executed some works at Sheerness, at the conflux of the Thames and the Medway, somewhat of the same nature, but in circumstances incomparably more easy to manage, than in the open stormy entrance of Plymouth Sound. He observed that such a work as that proposed by Messrs Rennie and Whitby, even supposing sufficient precaution to have been taken to prevent any injury to the harbour during its execution, and that the whole were completed in its greatest perfection, would nevertheless, by opposing throughout its extent a complete interruption to the water, occasion such eddies in the wake of the work, and such an increased action on the bottom and sides of the parts left open, as could not fail of forming shoals, more or less injurious, according to the nature of the soil, and other local circumstances. Mr. Bentham's plan was to sink in the sea, but in a line of direction different from that of the other engineers, a double row of cylindrical masses of stone work, leaving an interval between each two masses above, equal to their diameter; placing the masses in one row opposite to, and covering the intervals between, the masses in the other row. By this arrangement, while the two rows in conjunction formed a complete obstacle to the direct course of the waves, the tide or current would be allowed to pass freely between the masses, throughout the whole extent of the break-water; boats also and even small vessels might, in moderate weather, pass through the intervals without danger. Notwithstanding these objections and proposals, the scheme of Messrs. Rennie and Whitby, all circumstances duly balanced, was adopted by government, and ordered to be carried into effect. On a plan much of the kind proposed by Mr. Bentham, was begun in France, before the revolution, a project for forming an artificial roadstead, or place of anchorage for ships of war, in front of Cherbourg, on the north coast of Normandy. This place situated in the bottom of a wide open bay, on a part of the coast projecting considerably into the British Channel, lies only about 60 miles south from the Isle of Wight, and therefore offers a most advantageous position for watching the motions of British fleets, moving up or down the channel, or proceeding from or into the great place of rendezvous at Portsmouth or Spithead. Cherbourg possesses no natural qualifications for a shipping-station, being merely a tide-harbour formed by a small river falling into the sea. Basons had been excavated, and locks constructed in former times, by the means of which frigates and smaller vessels could be conveniently protected; all with uncommon ingenuity, and at a very moderate expence. It was not enough for an engineer in France to give proof of his genius and skill in his profession, in producing the *best* method of accomplishing any desired object; his great merit consisted in inventing how to accomplish that object, in the most *economical*, as well as the most *ingenious* manner. By giving this turn to the public mind, works of the highest importance to the state and to individuals were carried on, in that country, for sums which, in some other countries, would be regarded as utterly inadequate to the purpose. All persons charged

with the execution of public works, even those whom we call *civil* engineers employed in the construction of harbours, bridges, canals, roads, &c. were military men, regularly bred, and under due but liberal controul, enjoying rank and emoluments sufficient for their station in society. And an instance of a superior officer of the French corps of Royal Engineers, suspected, accused, tried, and convicted of recommending works which he well knew to be unnecessary, not to say prejudicial, that he might have an opportunity of enriching himself during their execution; or of conniving at, not to say inventing, enormous abuses and extravagant expenditure, in the management of the public monies, in order that he might be suffered, by the plunderers under him, quietly to amass his treasures; that a field-officer of engineers should be proved to have stooped so low as even to make false returns of the quantity of coals and candles necessary for his official business;—an instance of such degrading delinquency is perhaps unknown in the history of French military jurisprudence. How far the same remark can be applied to a certain other country, the constant rival and often the enemy of France, the records of the courts which take cognisance of such offences against duty, honour, and even common honesty, will bear ample but humiliating testimony. As Cherbourg possessed no outer harbour or road, such as Portsmouth possesses at Spithead, it became necessary to inclose a portion of the bay to answer that purpose. Piers or break-waters of continued construction were thought of: but at last it was resolved to sink a long range of wooden truncated cones into the sea, at certain distances asunder, which being afterwards filled with massy blocks of stone, would form a succession of solid immovable masses, sufficient to break the violence of the external waves, and render the space within incomparably more quiet and secure than it was in its natural state. The cones were strongly compacted of oak, narrower above than below, and resembling a deep tub standing on its base, without a bottom. By most ingenious contrivances the cones were floated out to their destined situation, by means of empty casks made air tight, which were afterwards detached, and the frame allowed to sink to the bottom. The sides were of sufficient height to be always above water, and when filled with stone withstood the action of the tides and waves. This great enterprise, the only thing of the kind in the world, was naturally interrupted by the disorders of the revolution in France, but was afterwards resumed, with great activity; so that in future wars with France, (and wars, notwithstanding the present violent fit of mutual affection by which the governments are said to be actuated, will without doubt arise,) Cherbourg may become a most troublesome neighbour to Britain.

Wooden bridges. Besides stone, timber is on many occasions employed to open a communication across a river; and in some cases it has greatly the advantage, as when the current is particularly rapid; for there the posts or piles supporting the road, presenting, either individually or collectively, but a small obstacle to the stream, often effectually resist its violence, when a stone pier, if it could easily be constructed in such a position, would not long keep its ground. Hence it is, that not only in our own country, but more particularly on the continent, stone bridges over great rivers are comparatively rare. Thus, on the Rhone, for instance, which, rising in the highest Alps of Switzerland, makes its way to the sea through the southern parts of France, bridges of stone have

often been constructed, and as often carried away by the stream, so that at this day, perhaps, not more than two remain. The Rhone is, however, the most rapid river of its size in Europe. On the Rhine, which, rising not far from the source of the Rhone, takes an opposite course through Germany and Holland into the German ocean, and is so much less rapid as its course is longer, stone bridges are quite unknown. But this is owing not only to the great body of water it carries along, but also to the policy of the different states along its banks, each unwilling that the opposite state should, by a standing bridge of masonry, possess means of making hostile attempts across the rivers. At Strasburgh, for instance, a large and prosperous city of Alsace in France, seated on the west bank of the Rhine, commanding by its fortifications a much frequented passage over the river into Germany, the bridge was, and, perhaps is, formed by ranges of piles driven into the river, from space to space, to form the piers, supporting rafters and planks for the road, kept in their place by wooden bolts or treenails; so that with a few strokes of a hammer or hatchet, the planks could be cast loose and removed, and all passage along the bridge effectually cut off. The German end of the bridge was also guarded by works, to prevent the French from penetrating by that communication. This is the bridge of Kehl, celebrated in ever history of hostilities between France and Germany.

Various are the methods employed in the construction of wooden bridges, governed principally by the extent of water they are to cross. Even in the narrowest, it is improper to trust to the resistance of beams reaching from bank to bank; for they ought to be trussed, that is, to be supported by pieces of timber reaching from each bank, near the water, obliquely towards the middle of the bridge. This contrivance will add greatly to its strength, and prevent its bending under passing loads. One of the most important particulars to be considered in wooden bridges, is the seasoning of the timber. It is well known, that the decay of fir timber is generally owing to the moist sappy nature of its exterior surface. This moisture must be completely removed before any paint or priming be applied, in the view of securing it from the weather. If left in its natural state, this sap would, by the action of the wind and heat, be gradually carried off, and the fir beam become internally dry and solid; but if the surface be covered with paint, oil, pitch, or other substance of this kind, the sap is confined, and will soon corrupt the timber, which will give way before its time, and without any external symptom of decay. In order to dissipate the moisture or sap of the surface, it is sometimes the practice to scorch the timbers over a fire, turning it round regularly. The heat will attract the moisture to the surface, and evaporate it; and the timber will acquire a hard crust, of great service in resisting the weather. When this is done, the parts that are to be under water should be carefully covered with pitch and tar, sprinkled with sand and powdered shells. Those which are more in sight, should, while the wood is still hot from the fire, be rubbed over with linseed oil mixed with a little tar, which will then strike deep into the wood, and soon become so hard as to be fit to be painted. Fir timber thus prepared is found to be nearly equal to oak in durability. At Schaffhausen, in the north part of Switzerland, was once to be seen a wooden bridge over the Rhine, there very rapid, so that no stone bridge could resist it, admirable in its construction, and as being the produc-

tion of a plain country carpenter. The builder was directed to avail himself of a part of one of the piers of the stone bridge still remaining in its place, to support the intended structure. With this order he apparently complied; but so contrived matters that, in the opinion of the best judges, his bridge actually consisted but of one immense arch of near 400 feet, (the breadth of the river) having a part stooping down, as it were, to rest upon the pier in the water, but not, as far as could be discovered, actually resting on it. With very long fir beams, prepared for the purpose, extended at an angle of moderate elevation above the horizon, from both sides of the river, and in conjunction with intermediate timbers, meeting over the water, two arches were formed, being segments of large circles, and resembling the circular frame of the centring of a stone bridge. These arches were placed parallel to one another, at a distance sufficient for the breadth of the road, which was formed upon timbers suspended from the arches on each side, so as to be quite horizontal from end to end; and instead of going over the supporting arches, was in fact let down in between them. The whole was roofed over, and inclosed at the sides, with windows at convenient distances, to defend the timber from the weather. This most ingenious and most useful piece of carpentry, which had gained the applause of all men of genius and skill, completely answered its destination from 1740, when it was constructed, to 1799, when it was wantonly and wickedly destroyed by French invaders. The horrible excesses and barbarities in which the French armies proudly indulged in Switzerland, during the late war, are in a manner unknown beyond the bounds of that country: ages, however, will not suffice to efface the remembrance of them from the memory of the Swiss. Could any thing have aggravated the the atrocities perpetrated by the French commanders, it was, that they were perpetrated for the pretended purpose of introducing virtue and freedom, and happiness among a people already eminent among the nations of the continent for happiness, and freedom, and virtue. Well was it observed in parliament, by one of the most valuable men this country ever produced, *Charles James Fox*, that, in their zeal for the propagation of liberty, virtue, and happiness over the world, the French had so liberally given away these invaluable possessions, as not to have reserved one atom of either for themselves.

Iron bridges. Bridges of iron are the production of British ingenuity exclusively. Iron being the great staple metal of the country, it has of late been employed in many works where great strength is required, in proportion to the weight of the materials. Melted or cast iron possesses several advantages over stone or wood; and these in their turn possess advantages over cast iron. To stone, iron is superior in tenacity and elasticity, and thence in strength, in facility of formation in any desired shape, and in extent of the masses in which it may be formed; qualities all conducing to its superior lightness and cheapness. To wood, iron is superior in the same particulars, together with durability; but in this last respect, stone has greatly the advantage over iron, equally exposed to the weather, or other natural agents. The greater durability of stone arises from its being less liable to decomposition from the atmosphere, and from its being less elastic, and consequently less subject to friction among its component particles, in yielding to the load and motion of carriages passing over it. Several ways may, however, be adopted, to remedy, in a great degree, these defects

of iron. Paint will preserve it from oxydation, or rusting, for many years, and the application may, when necessary, be repeated without much expense. Cast iron carriages of garrison guns have, by various external applications, been perfectly preserved for upwards of a century. The vibratory motion of an iron bridge may also be considerably diminished, by the manner of placing and connecting the bars of which it consists; so that each bar shall act as nearly as possible, at right angles, against another, and be at the same time so short, as not to be in danger of being bent or crushed by the pressure against its length. The greatest objection in this respect to cast iron is this, that on account of the imperceptible differences in the purity and other qualities of the metal, it is impossible to cast two bars or blocks, even in the same mould, which shall shrink perfectly and equally in cooling, and consequently be of precisely the same dimensions when employed in work. When such pieces come to be joined together, therefore, some empty space must necessarily exist among them, which, in a large work, where many pieces are employed, must produce a very sensible play in the joinings, and consequently great vibration, or reciprocal motion, in the whole structure. This inaccuracy of the joinings may, it is true, be in some measure corrected, by inserting pieces of sheet-lead in the joinings; but this metal possesses by far too little cohesion of parts, and too little elasticity to be of use for any length of time. In order to prevent the evils arising from these defects of cast iron, it has been proposed to fill up the vacant spaces, left between the iron framing, with some compact cheap materials, such as brick, united with the composition called Roman or Parker's cement, or pozzolana, or terras, which would readily and intimately combine with the iron; thus defending it from the action of the atmosphere. The interstices between the bars being thus also filled up by a consolidated substance, the play, friction, and vibratory motion of the bridge would be greatly diminished. Lightness being, however, a most desirable property, it has also been proposed to form hollow bricks solely for this purpose, which being carefully and thoroughly baked, or even semi-vitrified on the surface, would be proof against the effects of the atmosphere. In many parts of this island bricks are still seen, in remains of Roman buildings, fifteen or sixteen hundred years old, in perfect preservation, while the stones with which the bricks are built up in alternate layers, are often greatly decayed, unless when enveloped in the admirably constituted mortar of those days. Iron may be used for bridges either on the principle of equilibration, as stone is employed, or on that of connection, by framing, as wood is sometimes employed in bridges, but generally in roofing houses. For bridges of considerable dimensions, the former is, by many judges, esteemed the best mode; but for small bridges the latter mode will probably be found the cheapest. As iron bars, rods, or blocks, may be firmly connected together by bolts, or other means, an iron arch may be constructed much flatter, that is, in the segment of a much greater circle, than if it were of stone; an advantage of very great importance in certain positions where arches of great span are required. The first iron bridge of any note constructed in this country, was that of Colebrookdale, in Shropshire. It consists of five ribs, each of three concentric arches, bound together by pieces in the direction of radii of the circle. The interior arc forms a semicircle; but the others reach only to the sills under the road-way. These arcs pass through an upright frame of iron at each end, serving as a guide; and

the small space in the haunches between the frames and the outer arc is filled up with a large iron ring. On the ribs are laid cast iron plates to support the road. The span or opening of the arch is 100 feet 6 inches, and the height from the base line to the centre is 40 feet. The road along the bridge is 24 feet broad, formed on a bed of clay and iron slag, (the refuse from the furnace where iron ore is smelted) a foot in depth. Another bridge of the same material was afterwards erected over the mouth of the river Were, forming the harbour of Sunderland, a great coal port in the county of Durham. The peculiar construction of this bridge consisted in applying iron, or other metallic substance or compound, to form arches on the same principle with stone arches, by a subdivision into blocks easily portable, answering to the key-stones of a common arch, which, being made to bear on one another, will have all the firmness of a stone arch. At the same time by the great open spaces left between the blocks and their respective lateral distances, the arch becomes materially lighter than if it were of solid stone, and by the tenacity of the metal the parts are so intimately connected, that the delicate but indispensable calculation of the size and weight of the stones composing the arch, becomes of but little importance. This bridge is in span 236 feet, and as the stones from which the arch springs on each side project 2 feet, the whole opening is 240 feet. The arch is a segment of a circle of 222 feet radius, and the height from the chord to the top of the arch is 34 feet: but the whole height of the middle of the arch above the surface of the river at low water is about 100 feet, so that ships can pass under it. A series of 105 blocks forms one rib, and six of such ribs compose the width of the bridge. The vacant spaces between the arch and the road are filled up by cast iron circles, which touch the outer circumference of the arch, and also support the road, gradually diminishing from the abutments towards the centre of the bridge. Diagonal iron bars are laid on the tops of the ribs, reaching to the abutments, to keep the ribs from twisting. The superstructure is a strong frame of timber, planked over to support the carriage road, composed of marle, limestone, and gravel, with a cement of tar and chalk laid on the planks, in order to preserve them. The whole width of the bridge is 32 feet. The abutments are masses almost solid of masonry, 24 feet in thickness, 42 in breadth at the bottom, and 37 at the top. The weight of the iron in the whole work is 260 tons, of which 214 are cast, and 46 wrought iron. The expense of the whole, twenty years ago, was L.27,000.

Bridges composed of cast iron arches are now constructing across the Thames in London; one at the upper end of the town, opposite to Vauxhall, consisting of nine arches, resting on piers of Dundee stone; another a short way above London bridge, to consist of only three arches supported on stone piers, one of very great extent in the middle, with a smaller arch on each side. A third iron bridge is in contemplation, to be thrown over the river a good way below London bridge, to be of such an elevation in the middle that vessels of all sorts, resorting to the port of London, may pass under it, by only lowering the upper part of their masts and rigging.

CHAP. V.

OF PAINTING.

Of all the arts generally included under the appellation of *Imitative*, that of painting undoubtedly deserves the first rank; not merely for the beauty and diversity of the tints it affords, nor that artful disposition of light and shade which often deceives the eye, but for a higher consideration, namely, that of pourtraying nature in the most animated, lively, and interesting manner. It may be defined, the art of representing, by means of lines shadows and colours, every visible object in nature; and, expressing, by the lineaments of the countenance, and attitude of the body, the various emotions of the mind. On a smooth surface may be expressed objects, not only in such a state of projection, (and if the laws of perspective be observed) so effectually as to deceive the eye of the unwary beholder. They may be represented also in the most enchanting dress, and in a manner capable of affording delight to the senses. It is an essential characteristic of this art, that it addresses itself to the mind; and inspires us with pity for a suffering victim, with dread of an impending danger, with courage to imitate an heroic example, and with every other passion that has a seat in the human breast.

From this definition of the art it will naturally be conceived that its successful execution is attended with no small difficulty; it is the reward only of labour and assiduity: and, among its numerous followers, how few arrive at superior excellence! None can truly appreciate the value of the art, till they be fully acquainted with the difficulty attending its execution; nor the reward due to those finished productions, till by their own practical knowledge they are convinced of the frequent failures of many excellent artists.

The professors of this art are principally divided into two classes, namely those who speak to the eye, and those who apply to the mind of the observer. The former comprehends a very large group, and nearly the whole of the profession in every country of any single age in Europe. Among them we may include the generality of portrait painters, painters of landscapes, and all those who endeavour to convey conceptions to the spectator which are merely agreeable, but which do not interest the passions: many of those, undoubtedly, possess considerable merit, and may be ranked first in the style of decoration and embellishment. But the latter class, who apply to the mind, and who, by their artful delineation and colouring, convey those noble and profound sentiments possessed by themselves to the spectator, and who are more capable of fixing the attention than dazzling the eye, are of the highest order of artists.

That artist whose highest aim is to please, or astonish, the spectator, by the variety and opposition of tints, and illusion of colours, must rest satisfied with that secondary kind of fame, above which his merit will

never exalt him. No higher praise is due to that assiduous genius, who industriously groups together a great assemblage of objects in one piece, in order to give animation to his work, and fix the attention of the observer; whereas the general effects of such productions are confusion, from the multiplicity of characters, and consequently disgust. For in painting, as in poetry, it is only by adding sublimity to the sublime objects of nature, that the artist can truly merit, or ever justly obtain, those immortal wreaths which the nations of the world have unanimously decreed to Homer, Virgil, Milton, Raphael, Michael Angelo, and the statuary who modelled the ancient Apollo. So also, the poet who clothes trivial, or common ideas in verse, is at best but a maker of rhymes; while he, who delivers agreeable sentiments, and pleasing thoughts, in round flowing numbers, is generally distinguished by the appellation of a pleasing poet: but he who adorns great events, and noble and sublime sentiments, with all the imagery of numbers, is a great poet, and a successful painter of nature. He, and similar geniuses only, whether they express their sentiments in verse, or in colours, on brass, or on marble; whether painters, poets, or statuaries; deserve all the respect due to superior minds. They are of the number of these men whom nature, sparing of her best gifts, grants but occasionally to their fellow-creatures, to improve and elevate, with more refined sentiments, the general race.

Painting, like all the other liberal arts, is reducible, in a great measure, to certain generally received rules and precepts. And though these precepts, and perhaps all others that could be given, be alone (that is, without some portion of genius) insufficient to produce a good artist; yet they will almost at all times, prevent a man from being a bad one. They are the reflections of the greatest masters, and consequently demand the greatest attention. They point out those rocks which the student should avoid; and are, therefore, indispensable to his success. They facilitate his labours, and direct him in the shortest and surest road to perfection. They refine his taste, teach him to discover the truly beautiful in nature or art, and strengthen and confirm his judgment. It is art only, founded on just and proper rules, that is capable of divesting nature of her wild and savage appearance, and bestowing on her that grace, elegance, dignity, and politeness, which render her the object of our admiration.

The principal object of all the polite arts is *beauty*, and their theory consists of *genius and taste.*—*Beauty* is one of those terms of which we more readily conceive the meaning, without any definition, than by the most elaborate explanation. The more philosophers attempt to elucidate the sense of the term, the more they envelope it in darkness, and that in proportion to the different ideas men form of this quality, influenced by the prejudices of custom, education, &c. It may, however, in general, be affirmed, that beauty is the union of the various perfections of which any object is susceptible, and which it actually possesses; and that the perfections which produce beauty, consist principally in the agreeable and delightful proportions which subsist between the several parts of the same object; between each part and the whole together; and between the several parts, and the end or design of the object to which they belong. This general definition of beauty will always be found to hold good, in every object in which it can be found, notwithstanding several inferior requisites concur to its production. *Genius*,

by some confounded with invention, is that faculty of the mind by which alone beauty can be produced. *Taste,* or disposition, is no more than a natural sensation of the mind, refined by art. It serves to direct genius in discerning what is beautiful, and in producing beauty of every kind. Thus it appears, that the general theory of the polite arts is nothing more than the power of discovering what is truly beautiful. The man in possession of this theory is susceptible of all the enchanting power of the polite arts, whose force consisting in expression, applies to the mind through the organs of hearing, as well as those of sight. He is equally charmed with the melody of numbers, the harmony of sound, the productions of the pen, the pencil, the chissel, or the graver.

The *first* general rule necessary to every follower of the polite arts is *to consult his own genius ;* to divest himself of all self-love and partiality for his own merit, and carefully to examine whether he possess those properties indispensable to his success ; the principal of which is, *a lively and happy imagination ;* or, in other words, that inventive faculty of the mind which gives him a facility in always discovering something new. This assertion may sometimes damp the hopes of the young student, seeing so much has been done in every part of art by his predecessors. There have been many authors, in each of the polite arts, who may seem to have exhausted all the stores of imagination, and have left no materials for novelty or invention ; yet there is, perhaps, as much opportunity for the exercise of imagination now, as in the first dawnings of science. And though the fine arts, in their imitations of nature, can borrow images, figures, and comparisons, from those things only that exist and are known, nature is ever changing, and presents to an attentive observer an infinite variety of scenes. New situations of characters may present themselves to the artist's mind: new events take place, both in civil and domestic history ; former occurrences may also be rehandled with more success: figures may be grouped in an original and more pleasing manner: the different passions may be more strongly expressed, and the graces more pleasingly described, by one artist than by another. This power of invention consists in the ingenious use of combination ; by which any of the various objects of nature are brought together, disposed, and contrasted in such a manner as to form a whole, which is altogether new, happy, and agreeable ; which surprises as well as pleases ; in which we find a harmony, a perfection, a thought, an expression, quite unexpected, that we could not foresee, nor hope to find, in the manner the artist has so happily placed it.

In the examination of his powers the student should, however, be careful against passing too hasty a verdict on his own demerits : genius is, however, no more than an apt judgment combined with a facility of arranging disposing and uniting suitable objects, in a manner novel, pleasing and conforming to the principles of taste. This faculty is often the possession of the student, though he himself be ignorant of his powers. And still more frequently does it lie dormant in his breast, till the latent quality is brought forth by reviewing and endeavouring to imitate the excellence of others.

Secondly ; Every artist should incessantly endeavour to *improve his taste ;* or to acquire that sensible refined and clear discernment, which will enable him to distinguish the real beauties in each object, the ornaments that are agreeable to it, the proportions and relations that subsist among the several parts, and every other requisite that concurs to the

production of a finished piece. This practice will regulate and assist his natural talents. But, to attain his excellence, he must be acquainted with the opinions and reflections of the greatest masters, on every material part. He must constantly and assiduously study the great models of beauty, immediately connected with his pursuits; and finally, make his own observations on the properties of all those objects which relate to his art.

The *third* general rule is, to *imitate nature.* Every object in the universe has its peculiar nature, which the artist should always imitate in a proper manner. The most profuse ornaments and brilliant strokes, without a due attention to this great model, will never render his work perfect. This rule, though so obvious and necessary, has been too much neglected even by those who are justly considered as the founders of their respective arts. The sublime Homer has sinned against this precept, by representing his deities (who are supposed to be of a more refined and superior nature than mankind) vicious and depraved, vulgar and ridiculous, and that to a degree which would be unpardonable in a frail human being. This is a gross violation of this fundamental rule; others there are, easily committed, and less readily detected. It was not natural to make a hero, at the most critical moment of a decisive battle, deliver a long tedious harangue, which could not be heard by the thousandth part of a numerous army. These two instances of the violation of this rule, by the father and prince of poets, are noticed to show the student the danger of neglecting this direction. Numberless are the offences of this nature committed by artists, many of them eminent ones; they are strewed over some of the greatest beauties of art. Neither is this to be wondered at; for this imitation of nature, at first view so simple and easy, is of all things the most difficult in practice: it requires a more than ordinary penetration, and a power of expression rarely to be met with.

The *fourth* general rule is *perspicuity.* Nothing is more destructive to beauty and elegance, in all the fine arts, than an obscure ambiguous expression, encumbered with elaborate descriptions, and perplexed with too much contrast: while, on the other hand, plainness and perspicuity impart beauty to composition, of every kind, in each of the arts. Beauty must also be evident and striking to the most ignorant, as well as to the most learned; otherwise it ceases to be beauty: that beauty which requires an explanation, is, at best, but a spurious kind, and neither deserves the artist's attention, nor will it merit general approbation. A happy union of perspicuity, with a just imitation of nature, seldom fails of attracting admiration: and though other requisites may be wanting, those alone are sufficient at least to preserve a production of art from oblivion.

Elevation of sentiment forms the *fifth* general rule in the pursuit of art. This enables us to express each object in the greatest perfection of which it is susceptible; and thereby we imitate nature in her most exalted beauty. The artist must always raise his mind above his subject, to excite pleasure in others: he should choose the most favourable light wherein to place it; embellishing it with the greatest, most noble, and beautiful ornaments that his imagination can suggest, without departing from the imitation of his great model, NATURE.

Sublimity may be considered as the next and last general rule of art. It arises from the junction of the greatest perspicuty with the most ex-

alted sentiment. The most common subjects are as susceptible of being rendered sublime, according to their nature, as the most elevated ones. A poem, prose composition, or painting, are equally capable of sublimity. Truth also forms a principal part of the sublime. Every follower of the liberal arts should constantly aim at the attainment of this exalted excellence. Every thing that is low, unbecoming, or disagreeable, is naturally repugnant to this refined principle, which is founded only in what is strictly true, elevated, and perspicuous.

Of all the researches of man into the records of antiquity, that which concerns the origin of art has attracted the greatest attention. The more pleasure we receive from any refined invention, the more are we solicitous to discover to whom we are indebted for our entertainment. The ancients with a laudable gratitude, deified those benefactors to the human race, who, by their discoveries of useful or polite arts, had contributed to our convenience amusement or delight. The moderns, equally sensible of the same benefits, more rationally investigate the causes which led to those discoveries, the assistance those early artists received from nature, and the diffiulties they met with in their arduous endeavours; and thereby are enabled to draw a just comparison between the original inventor, and the most finished improver of an art, assigning to each his due share of merit.

The origin of most of the useful arts is undoubtedly nearly coeval with that of the human race. The erection of habitations, the preparation of food and clothing, even in their original simplicity, require some mechanical abilities, and experimental knowledge; and from their operations, and the utensils indispensibly requisite in their preparation, an infinite number of arts took their rise. Among those termed liberal and polite, many are of such high antiquity as to elude the inquiries of the most diligent antiquarians. Several have, as it were, crept into existence, without any known inventor, and made a gradual and imperceptible advance towards perfection, before they attracted the notice of the industrious historian. Painting, (or, in its most early stage, simply drawing,) falls under the latter class. The first idea of the art must, no doubt, have been formed by man, at a very early period: the shadow of objects, whether plants, trees, or animals, afforded him the means of conceiving, and dictated to him the possibility of representing bodies of a similar nature, upon a plain surface. Many of the most savage nations possess the first rudiments of the art prior to those which are more useful and necessary to existence. They stain their naked bodies with indelible colours, in the forms of animals, stars, &c. This seems to have been the first occasion man had for this art. He soon after made it subservient to civil purposes. It offered a more simple and intelligible method of recording historical events and warlike exploits, than that through the circuitous medium of alphabets of arbitrary characters, invented long aftewards. The hieroglyphics of ancient Egypt, and in latter days the picturesque writing of the Mexicans, answer this purpose.

The master-pieces of the art, in the earlier stages of its history, were not superior to the essays of children: it was not till after many years that they thought of rendering their imitation more complete, by the addition of different colours. This improvement was no more than the laying on of the simple colours, without any shade, in the same manner as maps are stained at the present day. Many nations, as the Egyptians,

Chinese, and several countries in India, rested satisfied with this state of the art, thinking they had brought it to perfection, and consequently never attempted any further improvement. More ingenious and refined countries, however, attended to the appearances of nature, and invented light and shade.

Egypt was the first country in which, we are informed, the imitative arts met with any encouragement. Plato, who lived four hundred years before the christian era, informs us that painting had been practised in Egypt for ten thousand years; that some of the productions of that high antiquity were then in existence: and that they exactly resembled those which the Egyptians executed in his time. By *ten thouand years*, our author, no doubt, intended a long indeterminate period. Without digressing into the different interpretations which have been given to this term, it is sufficient to show us the great antiquity of the art in Egypt, even in the days of Plato, as far as the impostures of the Egyptian priests deserve notice.

From what remains we possess of Egyptian painting, (the chests of mummies) we may at once perceive the rude state of the art, beyond which it never arrived in that couutry. Their only model was these mummies, from which also they derived their skill in anatomy; consequently their representation of the human form is ridiculous in the extreme. The general figure is stiff, the legs drawn together, and the arms pasted close to the sides. The face is still more distorted, the outline of which is nearly a complete circle, the chin short and rounded, the cheeks excessively so: The corners of the mouth and eyes turned upwards, and the ears placed much higher than the nose. Notwithstanding the proportions of the Egyptian artists have been extolled by some, who imagine the ancients can do nothing amiss it must be confessed, that they observe no proportions but the length. The breadths of their figures, as well as that of the muscles, are very erroneous. With regard to those monstrous objects we find in their works, namely, the bodies of animals with the heads of men, and the bodies of men with heads of animals, they were objects of divine worship, the figures of which were to correspond with the fables of their religion. It appears that they used but four colours, namely, blue, red, yellow, and green, which were laid on without any mixture, and without any shadings. The red and blue prevail most. They seem to have been formed of the coarsest materials, and with very little trouble. The outline of the figure was traced with black strokes; and the lights formed by leaving the parts covered with white lead, as is done by the white paper in some of our drawings. The ground on which they painted, was, in general, their earthen vessels, and drinking cups: they also ornamented their barges, and covered with figures the chests of mummies. It was but seldom they painted on cloth.

The ancient Persians were so ignorant of the arts, as to set a very high value upon the childish productions of the Egyptians, even after the Egyptians had become their captives. It has, however, been asserted, that the ancient Persians, as well as the Arabians, had some knowledge of Mosaic work. But as the principal merit of this work consists in copying the paintings of a great master, in a manner that cannot be destroyed, it is hardly to be thought that the means for the perpetuation of the art had attracted greater notice, and risen to higher excellence, than the art itself.

The modern Persians paint on cloth, as do also their rivals in this particular, the Indians. But the chief merit of the works of both these people consists in the strength and brightness of their colours. Their figures are purely capricious: they represent plants and flowers which have no existence in nature: and, like the ancient Egyptians, they confine the art mostly to the fabulous deities of their religion; namely, animals of their own creation, and monstrous idols with a multitude of arms and heads. It must be admitted that their artists discover a great degree of patience, united with a singular delicacy of the pencil. Some of the idols also, in Thibet, are executed in a certain stile of relief; but these praises are all that can be bestowed upon the *rationale* of their practice. Their figures are all destitute of beauty, and in common with many of the eastern nations, are quite deficient in style.

The Chinese seem to partake of the general poverty of the eastern countries, in their attempts in the fine arts, as is evident from the specimens on their porcelane ware; and travellers assure us, that their best works on the canvas, and on paper, are in no wise superior. They have not the least conception of perspective. Their landscapes appear destitute of any plan: in their clouds there is not the least variety of appearance. They discover no knowledge of forms in their human figures, no idea of proportion, and no expression of the most conspicuous muscles. A total ignorance of anatomy pervades all their works: and, like the other eastern nations, a few simple strokes serve them to express all their variety of figures. In a word, their principal object seems to consist in making their figures as unlike nature as possible. They are serious caricatures of the human figure. The beauty and durability of their colours, for which their works are often admired, are more the merit of their climate than of the artist.

The inhabitants of Etruria, now called *Tuscany*, were the first who improved the arts by the study of nature. In the days of Pliny the Etrurian painters were held in high esteem. Some paintings of these people, found in the tombs of the Tarquins, still remain. They consist of long painted frizes and pilasters, adorned with huge figures, which occupy the whole space from the base to the cornice. They are executed on a ground of thick mortar, and many of them are in high preservation.

Campania, at a very early period, received the rudiments of the fine arts from some colonies of Greeks, established at Naples and Nola. We have still remaining two medals, one containing the head of a young Hercules, and the other that of a Jupiter, executed in a masterly manner. The Campanians frequently painted on vases; the learned antiquarian, Winckelman, observes, "There have been discovered a great number of Campanian vases covered with paintings. The design of the greatest part of these vases is such that the figures might occupy a distinguished place in a work of Raphael. Those vases, when we consider that this kind of work admits of no correction, and that the stroke which forms the outline must remain as it is originally traced, are wonderful proofs of the perfection of the art among the ancients."

The first painter of any eminence in Greece, of whom historians have made mention, was Polygnotus of Thasos. He lived about 420 years before the christian era. Pliny informs us that he was the first who introduced drapery in his female figures. He also used different colours to the various paris of the dress; and was the first who ventured to draw the

mouths of his figures open, in such a manner as to shew their teeth. But it is certain that painting in dry colours was practised as early as the siege of Troy, or at least when Homer wrote the account of it; for in the Iliad Helen is represented as working on tapestry the figures of the numerous combats of which she had been the occasion. The buckler of Achilles also evidences their skill in that kind of sculpture called the basso-relievo. The art, however, may still be considered to have continued in its infant state till the succeeding age, which produced Zeuxis and Parrhasius, who were the first who added grace to the other excellencies. In the contest between these rival artists, Zeuxis resigned the palm of victory to Parrhasius, because, in a cluster of grapes he had painted, he deceived the birds who pecked at them; whereas Parrhasius, in a curtain which he had executed, and which seemed to conceal a picture, had deceived his rival Zeuxis, who attempted to draw it aside. The principal works of Zeuxis were his Penelope, in which, according to Pliny, he appears to express the manners of that princess; a Jupiter, surrounded by the gods; a Hercules, strangling the serpents in the presence of Amphitryon and Alcmene; an Helen and a Marsyas bound. From this list, and the fame these works acquired, it is evident the higher principles of the art were at that time begun to be studied. But Apelles, Protogenes, and Euphranor, carried it to the greatest perfection.

The Romans cultivated the fine arts, and raised statues to their kings, at the time when the arts were in their infancy in Greece. In the year of Rome 259 or 494 years before the christian era, Appius Claudius consecrated a number of shields in the temple of Bellona, which contained in basso-relievo, the portraits of his family. The exection of this work evidences that they understood painting, at least in one colour. But it is generally believed they employed the artists of Etruria and other nations. The first of their own country who excelled in the art was one of the Fabii, surnamed *Pictor, the Painter,* from his adopting the art of painting for his profession: he painted a temple in the year of Rome 450: and his works remained till the temple was destroyed by fire. Near a century and a half elapsed before the art found another cultivator in Rome, when Pacauvius, nephew of Ennius, painted the temple of Hercules in the *Forum Boarium.* But a true respect for the arts, and the desire of improving them, did not appear in Rome till the time of the emperors. The national spirit was then become somewhat changed, and the views of the people more disinterested. The first painting on cloth, among the Romans, was a colossal picture of 120 feet in height, painted by the command of the emperor Nero, concerning the merits of which authors are by no means agreed.

With the decline of the Roman empire, and the consequent fall of every art and science, the fine arts partook of the general torpidity. And painting, in particular, met with no real improvement in Europe till the beginning of the fourteenth century of the christian era. The first attempts in the modern history of the art were made in Italy; but there the artist was employed in representing the mysteries of the passion, and subjects of a similar nature, on the walls of churches and chapels. Their works were directed to a vast number of figures rather than to the beauty and perfection of each; and in our time the art has scarcely shaken off this absurd fault contracted at that early period. The modern artist (unlike the ancient Grecian) is not generally at liberty to

devote his talents to men of knowledge and discernment only, he is constrained to please those who are rich, and very often those who are ignorant. Instead of aiming at perfection in his art, his character, if not his existence, is connected with the caprice of his employer, or of an absurd prevailing taste.

The first considerable improvement made in the modern history of painting was that effected by an attention to the rules of perspective, which had too long been slighted: and Dominico Ghirlandajo, a Florentine, about the same time, greatly enriched composition by his then superior style of beauty in his figures: but his successors far excelled him in that respect.

The subsequent history of this art consists in an enumeration of the principal merits of some of the most eminent masters who have contributed their share of knowledge to the general fund. It is not possible, within confined limits, to give the particulars of the modern history of an art which possesses so many excellencies, and towards which the labours of so many have been directed: a relation of the principal qualities must therefore here be sufficient.

Towards the end of the fourteenth century appeared greater luminaries in painting than the art has ever since witnessed; and (considering its low state at that period,) geniusses who made greater improvements than could reasonably be expected; namely, Leonardo da Vinci, Michael Angelo, Giorgione, Titian, Bartholemeo de St. Marc, and Raphael. Leonardo da Vinci invented a great many details in the art, too numerous to find a place here. Michael Angelo, by his great skill in anatomy, and attentive study of the ancients, arrived to a greater excellency and elegance, in drawing the outlines of his figures, than any of his predecessors; and left examples to excite the admiration of his followers. Giorgione greatly enriched the general practice of the art by his easy and graceful manner, and by the brilliancy of his colours. Titian may be said to have perfected the truth of nature, and the tone of painting, by his strict adherence to the hues and general appearance of natural objects. Bartholemeo de St. Marc discovered the *chiaro oscuro.* He particularly studied drapery, and possessed the singular power of shewing the naked figure under the cloathing. Raphael, endowed with a superior genius, united in himself the various excellencies of both his predecessors and contemporaries: but his chief merit, and that in which he is still unrivalled, was a most happy power of invention and composition. To these eminent artists, shortly after succeeded Corregio, who, like the Apelles of Greece, carried the art to the greatest degree of perfection; and by that grace and beauty he conferred on his works, rendered his paintings the object of universal admiration. The illiterate stood astonished at his productions, and the churlish critic allowed them to exceed his dry rules.

From a strict attention to the works of Corregio, were produced the Carracci, at Bologna: the pupils of these artists formed themselves into a school, among whom Guido rendered himself particularly eminent for his graceful rich and easy style. Pietri di Cortona applied himself to composition, and distinguished it from invention. He, however, applied himself too asiduously to the contrasting of his groups; and introduced that absurd practice of loading his pieces with a great number of figures.

The seventeenth century gave birth to a Carlo Maratti, who was the

first who ventured to depart from a servile imitation of natural objects; but, like Cortona, he has offended taste by the great number of figures he introduced into his pieces.

From this short account it appears that the above-named great improvers of the art, following the manner of the ancients, and taking nature for their guide, carried every part of their profession to the highest degree of excellence. But their followers greatly degenerated from their laudable practice, and thus deranged the art, instead of further improving it, by availing themselves of the many excellent examples they possessed. It must be confessed, the Carracci, Paul Veronese and his contemporaries, Vandyke, and in general the Italian, Flemish, and French masters, supported it even after the seventeenth century with great brilliancy: but when the number of artists was increased, the practice of servile copying became general; and the confined ambition of aiming at one particular excellence, to the neglect of all the rest. Some considered the chief merit of the art to consist in colouring, and thus produced pieces of the greatest exaggeration; while others affecting simplicity, became cold and insipid. Men of real abilities, in endeavouring to avoid the other popular errors, departed from the road of truth and nature. They affected a pompous style, and endeavoured to attain what was then styled an expert management of the pencil, which may be seen in the fantastical attitudes, poignant effects, and other ingenious but vicious contrivances of certain French masters, since the days of Le Brun.

Among the numerous causes which have conspired towards the decline of painting, may be observed the following in particular:—It has been customary of late for the patrons and propagators of the art to be more assiduous in increasing the number of artists, than in singling out those who are by nature best adapted to the work. Schools for the qualification of a painter, very different from those formed by able masters of the art, have been greatly multiplied, where the elements are given in a dry uniform system of rules, by which the mind is shackled with many needless precepts, and the hand crampt by a slavish attention to them. By this method painters of inferior merit are produced, and that in such numbers as even to threaten the utter downfal of the art. The great reputation of the Italian painters has also contributed to the decline of painting. The rich and ignorant of all nations, desirous of being thought to possess taste, have earnestly sought for Italian pieces which they thought could not be too dearly purchased. Numbers, therefore, applied themselves to the manner of the Italian school, considering it as the best model for imitation, and the only medium for the attainment of profit and fame; and this still farther increased the number of secondary professors, without adding a single improvement to the subject. An arbitrary despotism, which has also reigned in the academic societies, has contributed not a little towards this evil. They have generally been governed by men who would direct the student's attention to one single object only. Every excellence of the art was to be neglected for the pursuit of one peculiar beauty. As an illustration of this may be mentioned the absolute and unexceptionable manner in which the governors of those societies proposed to their disciples the unremitted study of design, in exclusion of every other grace, while statuary was held in chief estimation. The artist, whose abilities and inclination led him to colouring, was, consequently, obliged to abandon

a subject, for the pursuit of which he could expect no reward, and apply himself to that for which nature and his own previous application had not qualified him: while on the other hand, he, devoted to the choice of exactness of forms, who was so unfortunate as to be a pupil of that preceptor who preferred colouring, found himself in a still greater dilemma than the former, considered his own incompetence in that particular branch as the want of genius, and was thus, perhaps, for ever lost to the art.

The Practice of the Schools.

All the painters of Europe, since the revival of the art, are divided into different classes, called Schools, each of which have learnt the principles of the art from a certain master, or else followed his manner; and have, consequently, each their peculiar characteristics. They compose the following: viz.—1. The Florentine School.—2. The Roman School.—3. The Venetian School.—4. The Lombard School.—5. The French School.—6. The German School.—7. The Flemish School.—8. The Dutch School.—And 9. The English School.

The Florentine School has an undoubted title to our preference, as being the first in Italy that cultivated the arts. It was founded by Cimabue, the descendant of a noble family of Florence. He was born in the the year 1240. He was the first who translated what little remained of the art, from one or two Greek artists, into his own country. And though his works were (as might naturally be expected) in an ordinary style, they received the applause and approbation of his fellow-citizens. His success soon excited emulation; and the art had so many followers, that in the year 1350, they formed themselves into a society, under the protection of St. Luke. Early in the fifteenth century, Massolina arose. He was a considerable addition to this school. He taught them how to impart grandeur and sublimity to their figures, to drape them gracefully, and to give them more life and expression than they had hitherto done. Massacio, his pupil, succeeded him: he was the first who, to the other qualifications this school possessed, added force animation and relievo to his figures. But the glory of this class, and the boast of all succeeding artists, were Michael Angelo, and Leonardo da Vinci, contemporary painters. Michael Angelo was undoubtedly superior to Leonardo in grandeur and sublimity; in that boldness of conception which conceives, and successfully executes, the most difficult subjects; and in a perfect knowledge and practice of design: but Leonardo was more successful in expressing the softer passions, raising agreeable sensations, and in a word, in all the amiable parts of the art: in these expressions he was surpassed by Raphael only. His works also were not altogether void of greatness: he made a very happy choice of his objects for imitation: his design was chaste, and often elegant; and he never went beyond nature.

But that great luminary of the art, Michael Angelo, sought rather the great and terrible than the pleasing and graceful. His perfect skill in anatomy enabled him, more than any other artist, to express exactly the joinings of the bones of the human body, and the office and insertion of each muscle. An ingenious connoisseur [Mengs] informs us, that " in his figures the articulations of the muscles are so

easy and fine, that they appear to be made for the attitude in which he represents them. But the fleshy parts are too much rounded, and the muscles are, in general, too large, and of too equal strength. You never perceive, in his figures, a muscle at rest; and though he knew admirably well how to place them, their action was very frequently inconsistent with their situation." This critique, though somewhat severe, is in general just, for whoever examines his pieces will observe too apparent a display of the muscles, particularly in his children women and young men, where they should be considerably more softened than in the vigour of manhood. From one of his own records we learn, that he first modelled, in earth or wax, all the figures he intended to paint. This was the general practice in his time, and is undoubtedly very commendable, as the artist has an opportunity of viewing them in relievo. Sir Joshua Reynolds observes of this great man, "If any man had a right to look down upon the lower accomplishments as beneath his notice, it was certainly Michael Angelo; nor can it be thought strange that such a mind should have slighted or have been withheld from paying due attention to all those graces and embellishments of art, which had diffused such lustre over the works of other painters."

From this account of the principal founders of this school, it is not difficult to discover wherein the principal merit of this class of artists consists. Their first and principal characteristic is greatness: their figures are animated, and seemingly in motion; a certain gloomy severity, and an expression of strength, by which grace is in a great measure excluded, pervade all their works; they possess a certain gigantic character of design, an appearance of majesty, bordering upon the divine, which seem to elevate human nature above mortality; and also, like their great master, they seem to consider the art of pleasing as undeserving their attention.

The Roman school may be considered as a production from the ruins of the art in Greece. It undoubtedly received the first rudiments from the works, or the artists, of that ancient enlightened nation. From the Greek statues they derived their knowledge of design, the beauty of exquisite forms, greatness of style, and justness of expression. They also improved upon the drapery of the Grecian artists, by making it more full and flowing than can be done in sculpture. This school was devoted to the principal parts of the art, namely, the effects of genius and vast conception; paying no more attention to colouring than was necessary to distinguish a painting, varied with colours, from the *chiaro oscuro*.

The founder of this school was the great Raffaelle, or Raphael Sanzio. He was born at Urbino, in the year 1483. He was pupil to Pietro Perugino, whose manner he first copied, but which he soon after laid aside for the imitation of nature only. He travelled twice to Florence to study the great artists who flourished in that city. It has been observed, that it was fortunate for him that he was born in the infancy of the art, and that he had formed his own manner, by attending to nature, before he had access to the works of any great master. He began by studying, with great exactness, the simple truth in his figures: he was at that time ignorant that any choice was necessary; but when he saw the works of Leonardo da Vinci, Massacio, and Michael Angelo, his genius took a new turn. He perceived, for the first time, that,

in order to excel in the art, something more was necessary than a simple imitation of truth. Sir Joshua Reynolds observes, that had it not been for Michael Angelo we should never have had Raphael. The works of those Florentine masters were, however, not sufficient to direct him fully in his choice. He resolved to travel to Rome, where he was in hopes to meet with those perfect models he so much wanted. On his arrival in that city he was not disappointed in the high expectation he had formed: he imitated those incomparable models, and in so doing he most effectually succeeded, and found he only followed the natural impulse of his own genius.

As he was always habituated to the imitation of nature, he found no difficulty in following the manner of the ancient Greeks, who taught him only the method of copying her with precision. He quickly discovered that those great artists did not enter into minute details; that they selected what was great and beautiful only; that they strictly adhered to proportions; that they paid particular attention to the joining of the bones, and giving a free articulation to the various parts of their figures. On imitating these excellencies, every one who has seen his works can judge how far he succeeded. He is justly considered as the great master of design, though it must at the same time be acknowledged, that in this part he was not so perfect, nor so finished, as the Grecians. This arose from his first imitating the basso relievos at Rome, which gave a certain hardness to his works: for we see more of the Roman than the Grecian in his design; the bones and articulations are strongly marked, and the fleshy parts less laboured; his proportions, however, are all very accurate. He excelled in representing grave and moral characters, as philosophers, apostles, &c. but he did not so well succeed (at least not equally with the Greeks) in ideal figures, which ought to carry with them an air of divinity. It is true, he seldom had occasion to represent such figures; the spirit and manners of his age forbade it; and the subjects he treated of did not require it. He thought it more requisite to attend to expression. In an art which represents the actions of men, the passions of the soul ought to be fully pourtrayed, as being the chief causes of those actions. His chief attention, therefore, in composing a piece, was to consider carefully the expressions of the passions which animated the different characters: and next, to mould all the figures, all the accessories, and all the parts of the composition, to the general expression of the whole.

In the *chiaro oscuro* he was comparatively weak; and what he possessed peculiar in the distribution of his light and shade he owed to the Florentine painters. It must not be inferred, however, even with regard to the *chiaro oscuro*, that he imitated nature without taste: he delighted in what are called great masses of light; and disposed the great lights in the most conspicuous places of his figures, whether naked or in drapery. Though this method is not very favourable to illusion, it gives his pieces distinctness, and makes his figures conspicuous at a distance, which is a very essential part of the art. His chief excellencies were composition, and the *ensemble* of his figures. He considered the art as designed to speak to the soul of the observer; and his philosophical mind refused to delineate objects that had no expression. Of the two principal kinds of composition, namely, the expressive, and the theatrical or picturesque, Raphael chose the former. Mengs observes, "He never indulged himself in common ideas, and was never allured

to give any thing in his accessory figures which might turn the attention from the principal object of the piece."

Sir Joshua Reynolds, in contrasting the merits of Raphael and Michael Angelo, observes, "If we put these great artists in a light of comparison with each other, Raphael had more taste and fancy, Michael Angelo more genius and imagination. The one excelled in beauty, the other in energy. Michael Angelo has more of the poetical in operation; his ideas are vast and sublime; his people are a superior order of beings; there is nothing about them, nothing in the air of their actions, or their attitudes, or the style and cast of their limbs or features, that puts one in mind of their belonging to our species. Raphael's imagination is not so elevated, his figures are not so much disjointed from our own diminutive race of beings, though his ideas are chaste, noble, and of great conformity to their subjects. Michael Angelo's works have a strong, peculiar, and marked character; they seem to proceed from his own mind entirely; and that mind so rich and abundant, that he never needed, or seemed to disdain to look abroad for foreign help. Raphael's materials are generally borrowed, though the noble structure is his own. The excellency of this extraordinary man lay in the propriety, beauty, and majesty of his characters; his judicious contrivance of composition, correctness of drawing, purity of taste, and the skilful accommodation of other men's conceptions to his own purpose."

The Venetian school is of an inferior class, and distinguished only for a certain splendour of style, but at the same time destitute of the truly great style. These artists, denied the privilege those of the Roman school possessed, namely, that of studying the precious remains of antiquity, and thereby acquiring just ideas of the beauty of form and expression, attended to colour, a pompous display of figures, a profusion and variety of drapery, and a certain tumultuous bustle, which they falsely considered to be animation. They were chiefly delighted with the beauties of the mixture and variety of natural colours, in which they succeeded. They not only characterized the objects by comparison, in making the colours proper for one of more value by the colour more proper for another; but they also, by the agreement and opposition of coloured objects, and by the contrast of light and shade, produced a vigorous effect, which at once demands and fixes the attention. The founders of this school are Giorgione and Titian. The former, dying in the 32d year of his age, was soon forgotten in the superior works of his contemporary and rival Titian, who improved upon his idea of colouring, and soon exceeded that servile manner of copying nature, into which he had been initiated. Few need be told that the excellency of Titian consisted in colouring. And, like the other artists of the same school, he paid little or no attention to historical truth, even in those pieces where it is expected.

It must, however, be acknowledged, that he is not destitute of great and noble conceptions. In his male figures he often discovers a considerable degree of grandeur: like Michael Angelo, he has sometimes overcharged his design, but it is chiefly in the soft and fleshy parts: and seldom does he err on the side of vigour and muscular strength.

As his principal object was simple imitation, in a display of the colours of nature, he neglected both the *chiaro oscuro* and justness of design. It is to the success of his imitation of colours that his defect in

the *chiaro oscuro* is owing: it is, therefore, not for these perfections that we are to seek in his works. His excellencies consist in the happy disposition of colours, both local and proper, and which he carries to the highest pitch of perfection, beyond any of his predecessors or followers. His practice was to paint in oil, and to finish his work from the objects in nature; which, joined to his superior talents in this branch of the art, gave a greater degree of truth to his colours than is to be found in the productions of the artists of the Roman and Florentine schools, who painted most commonly in water colours, or in fresco, and finished their works from their first sketches. His practice also, as a painter of portraits and landscapes, tended, in a great measure, to qualify him in colouring: by the former he was accustomed to the colours of nature and draperies individually, and the latter taught him the general rules of nature in the gross.

"As Titian perceived," says Mengs, "that the objects which are beautiful in nature have often a bad effect in painting, he found it necessary to make a choice in the objects of imitation; and he observed that these were objects of which the local colours were extremely beautiful; which, nevertheless, were, in a great measure, destroyed by the reflexion of light, by the porosity of the body, and by different luminous tints, &c. He perceived also, that in every object there was an infinite number of half tints, which conduced to the knowledge of harmony. In short, he observed in the objects of nature a particular agreement of transparency, of opacity, of rudeness, and of polish, and that all objects differed in the degrees of their tints and their shades. It was in this diversity he sought the perfection of his art; and in the execution he moderated the effect of natural colours. For example, in a carnation, which had many demi-tints, he confined himself to one; and he employed even less than a demi-tint, where there were few in the natural object. By these means he obtained a colouring exquisitely fine; and in this part he was a great master, and deserves to be carefully studied."

On the closest examination of the works of Titian it is impossible to say with what colours he produced his tints, the colours are so mingled together; which distinguishes his works from those of Rubens, who placed his colours one at the side of another. This practice of Titian enabled him so exactly to imitate the colours of nature; and gives a marked distinction to his works, whereby they are readily known by every connoisseur. Titian's landscapes present well-chosen situations; his trees are exquisitely varied in their forms, and their foliage well conceived. He had also the faculty of rendering his landscapes striking, by the introduction of some remarkable appearance.

Tintoret Paul Veronese and others of this school have uniformly distinguished themselves by their skill in the mechanism of painting only. They seem to have possessed no higher ambition than to succeed in the inferior parts of the art; and assiduously endeavoured to display those inferior qualities which the grand style teaches to conceive Paul Veronese so far sacrificed all the rules of the art, in his picture of Perseus and Andromeda, as to represent the principal figure in shade, merely to shew the effect of light and shadow. Every rule is rejected to that intent, and the capricious composition of that picture suited the style which he professed.

The mechanical excellence attempted by the Venetian school has been called the *Language of Painting*, in which these masters must be

allowed to excel: but here, as in most other cases, they have displayed more copiousness than choice, and more luxuriancy than judgment. If we consider the uninteresting subjects of their invention, or, at least, the uninteresting manner in which they are treated; if we attend to their capricious compositions, their violent and affected contrasts, whether of figures, or of light and shade; the richness of their drapery, and at the same time the mean effect which the improper introduction of coarse stuffs gives to their pictures; if to these we add their total inattention to expression; and then reflect on the conceptions and the learning of Michael Angelo, or the simplicity of Raphael, we can no longer dwell on the comparison. Even in colouring, wherein their chief merit consists, if we compare the quietnes and chastity of the Bolognese pencil to the bustle and tumult that fills evey part of a Venetian picture, without the least attempt to interest the passions, their boasted art will appear a mere struggle, without effect.

The Venetians are no less unfortunate in the invention of their pieces. Their subjects are generally such as admit a great number of figures, namely, feasts, marriages, processions, public martyrdoms, or miracles. They vainly conceive that a great variety of personages gave the painter an opportunity of shewing his dexterity of managing and disposing the masses of light and groups of figures, and of introducing a variety of eastern dresses and characters in their rich draperies. Even in the effect of their colouring, as before observed, they are very often inferior to the other Italian schools, as far as relates to the truly great style. It has been justly observed, "That their colouring is not only too brilliant, but too harmonious to produce that solidity, steadiness, and simplicity of effect, which heroic subjects require, and which simple or grave colours only can give to a work." Michael Angelo having seen a picture of Titian, told Vasari who accompanied him, "that he liked much his colouring and manner;" but added, "that it was a pity the Venetian painters did not learn to draw correctly in their early youth, and adopt a better manner of study." If this censure applied to a picture of Titian, with how much more weight would it fall on the works of Paul Veronese, Tintoret, and others of the same class. Of Tintoret in particular Vasari remarks, "of all the extraordinary geniuses that had ever practised the art of painting, for wild, capricious, extravagant, and fantastical inventions; for furious impetuosity and boldness in the execution of his work, there is none like Tintoret; his strange whimsies are even beyond extravagance: and his works seem to be produced rather by chance than in consequence of any previous design, as if he wanted to convince the world that the art was a trifle, and of the most easy attainment."

The Lombard school was founded by Antonio Allegri, commonly called Corregio, who was also the greatest ornament of this class of artists. The productions of this school are characterised by grace, a pleasant taste for design, a mellowness of pencil, and a beautiful mixture and harmony of colouring. But at the same time it must be observed, that the designs of the Lombard school are seldom correct; though from the gracefulness of their figures, the richness of their colours, and just gradations of shade, they generally produce an agreeable effect.

Corregio, in his imitations of nature, seemed to have principally in his view, grace, grandeur, and harmony. To produce these he sedulously strove, in his outlines, to avoid all short turnings and unnecessary angles;

and when the latter occurred, he endeavoured to make the lines which formed them arched and undulated. He not only rejected all small figures, as inimical to grace, but made his other figures as large as possible, and at the same time elegant, which, with his utter rejection of all acute angles and strait lines, gave his pieces that inimitable degree of grace for which they are still so much admired.

As he painted in oil, he possessed an opportunity of giving a tone to his pictures, and thereby creating in them grandeur of appearance. By attention to natural objects he perceived that shades should be represented by transparent colours, without which obscurity in painting can never be fully produced: for the rays of light being absorbed in the colours give less reflection. He also increased his obscure shades, by a method of glazing which he adopted, and skilfully managed,. His theory of colours and light he founded on his observance of an immutable law in nature. He laid his colours very thick on the brightest parts of his picture, in order to make them capable of receiving, by a proper touch of the pencil, the greatest degree of light; and he endeavoured to produce that effect of nature, whereby the light reflected from coloured bodies always corresponds with the colour of the body from which it is reflected.

He early perceived that harmony and grace were inseparable. To produce the former he constantly avoided strong oppositions, and violent contrasts. His pieces possess that easy gradation, from one extreme to another, which is the principal characteristic of harmony. Between his lights and shades he always introduced a space, which served at once to unite them, and to form an easy passage for the eye from the one to the other. He also knew better than any other artist how to relieve the eye after a violent exertion: he, therefore, after a bold and prevailing colour, always placed a demi-tint. In a word, he had a most delicate taste in colours, a perfect knowledge of the *chiaro oscuro*, and excelled in that essential part of uniting two lights or two shades. Many of his objects appear perfectly detached from the ground of the piece; and, for inimitable grace and perfect harmony, he is distinguished from all others.

The student must, nevertheless, beware of this great man's defects, and learn to distinguish between his real merit and his imperfections; for, like all the most eminent in the fine arts, he was by no means infallible in his outlines; notwithstanding his ease of design and taste in that part, he was far from being always pure and correct. His shades also deserve greater commendations bestowed upon them than the light parts of his pictures, which are too clear and somewhat heavy. And the fleshy parts of his subjects are not sufficiently transparent. These, however, are but trifling imperfections; and more than sufficiently compensated by the grace, grandeur, and harmony of his pieces.

Besides the foregoing class there is another society, known by the name of *The Second Lombard School;* sometimes called, *The School of Bologna*, It was founded by the three Carracci, namely, Lewis, Augustin, and Annibal. The two latter were the pupils of Lewis, who, in his manner, endeavoured to imitate Corregio. Sir Joshua Reynolds considers him as the best model for what is called *style* in painting:—"Lodovico Carracci (I mean in his best works)" says he, "appears to me to approach the nearest to perfection; his unaffected breadth of light and shadow, the simplicity of colouring, which, holding its proper

rank, does not draw aside the least part of the attention from the subject; and the solemn effect of that twilight, which seems diffused over his pictures, appear to me to correspond with grave and dignified subjects better than the more artificial brilliancy of sunshine, which enlightens the pictures of Titian." Lewis, it is true, had less fire, but more gracefulness and grandeur than the other. Augustin was a man of an enlightened mind, and, consequently, refined taste. He cultivated his understanding by his attention to the *Belles Lettres,* and devoted part of his time to poetry and music; and at the same time to dancing, riding, and other manly exercises. He possessed a great and vigorous spirit, which he always displayed in his pictures; and discovers in them a certain pleasantness of composition. Annibal, in his manner, appears to have fluctuated between an imitation of Corregio and Titian; his principal character is boldness, a profound and just design, a fortunate expression, and sublimity of execution. In beauty and design he is allowed, by some, to be a perfect model for imitation: but this praise is somewhat too unlimited, and has been fatal to many artists, who, in copying his manner, have often imitated his imperfections. It is true, he was very successful in his figures of ancient statues, though, as must naturally be perceived, he fell short of his originals, to which his imitators should resort.

The French school, from the various manners of its artists, has no peculiar character; some of its principal members have been formed on the Florentine and Lombard manner, others on the Roman, others on the Venetian, and a few have distinguished themselves by a manner which may be called their own: consequently this school unites, in a moderate degree, various different parts of the art; but does not excel in any one of them.

Poussin, though anterior to the French school, was one of the greatest painters of that country. His style and character are simplicity, cheerfulness, purity, and correctness. His works have more the air of antique painting than those of any other artist. His best performances are remarkable for a dryness of manner, which (though it is not to be imitated) perfectly corresponds with that ancient simplicity for which his style is distinguished. But in the latter part of his life he adopted a more soft and rich manner, and made the union between the figures and the ground much more apparent. His favourite subjects were ancient fables, for which his knowledge of mythology and ancient history perfectly qualified him. It was his fortune, however, and the fate of the French school, that he was more admired than imitated, and had not the least influence in forming the manners of the artists of that country. This honour was reserved for Simon Vouet, the enemy and persecutor of Poussin. Vouet, though a man of distinguished abilities, was very incompetent to establish any manner of painting: and had this school then been founded, persevering upon his principles, its existence would have been of very short duration. He had a kind of grandeur, joined to such a facility, that it was said of him, he need only take the pencil in his hand to finish, with one stroke, the subject he had conceived: but his design was false with regard to colour, and his figures were wholly destitute of expression. He, however, had the merit of destroying the insipid manner which pervaded that nation, and of pointing out the road to a better taste, which was pursued and brought to perfection by Le Brun.

This artist was the pupil of Vouet, whom, as well as his contemporary pupils, he astonished by his rapid progress. So early as at the age of twenty-six he finished his piece called *The Horses of Diomede*, which obtained a place in the Palais Royal, beside those of the most eminent painters. He was recommended to Poussin; but the young artist was more disposed to follow that modern part of the art, called *The Great Machine*, than the remains of Greek antiquity. Poussin was, nevertheless, of great service to Le Brun. He pointed out to him the necessity of obtaining some knowledge of the ancients; and directed him in his study of their monuments, customs, dress, architecture, rites, spectacles, &c.

Few artists have united so great a number of excellencies, many of them essential qualities, as Le Brun. He added a great conception to a most fertile imagination, to which his execution was mostly adequate: but he chiefly excelled in exact likenesses, and a rigorous observance of the costume. It is admitted, that he has many superiors, but their precedence consists in possessing some peculiar quality, in a more eminent degree than a man of Le Brun's extensive acquaintance with the various parts of the art could possibly obtain. He was an excellent drawer, and in his design he imitated Annibal Carracci. In his draperies he followed the manner of the Roman school. He did not identify the particular sorts of clothing, like the Venetians; his draperies were general; they were clothes and nothing more, which happily agreed with the heroic style, From his treatise on the character of the passions we may perceive that he had assiduously studied the expression of the affections of the mind, in which (notwithstanding the deficiencies he has been charged with in this subject) he has far excelled all others; and established some general truths and leading principles, by which many, or most, of the principal artists, since his days, have considerably profited; though, as is too often the case, their envy at his success, in this then untrodden path, will not permit them to allow him his due share of praise. His chief attention was directed to great compositions, and no man was more happily adapted to that mode of painting, nor possessed the power of bestowing more life animation and variety on his pictures than Le Brun. He had a most fertile imagination; and as he delighted in allegory, he had the greatest scope for invention; and the great resources of his mind appear very apparent in the introduction of symbols for his allegorical figures, not resting satisfied with those employed by the ancients. In colouring he surpassed the artists of the Venetian school, aiming at the higher excellencies, and the more solid tone of colour displayed by the schools of Rome and Lombardy, whose manner he also imitated, in his bold easy and agreeable management of the pencil.

Such are the perfections of this great artist of the French school: but numerous excellencies are seldom without their proportionate number of defects. His many followers, by an indiscriminate imitation of his various qualities, have considerably increased his failings, as well as created more, all which have been magnified by the cold eye of criticism. It is objected to his merits, that in design he was less eminent than Raphael, less pure than Dominichino, and less lively than Annibal Carracci. His expressions of the passions have been censured as too confined, and not displaying the prodigious variety of gradations, by which the various interior affections are indicated in the countenance. To this it may be answered; this subject is too infinitely varied in its appear-

ance, and too much extended in its objects, ever to admit of a delineation by a human pencil. Le Brun has effected greater things in this branch than any other artist; and those who are the most severe in their animadversions have contributed the least to supply his deficiencies. If, in his symbolical figures, he dealt somewhat in the fanciful, we must consider it only as the exuberance of a luxuriant imagination, and indissolubly connected with the more rational part of his invention.

Contemporary with Le Brun was Eustache Le Sueur, the rival of Le Brun; he added some degree of celebrity to the French School. He approached nearer to Raphael than any other artist, not only in the art of drapery, in placing his folds in the most easy and graceful manner, but also in expressing the affections of the mind, in varying the air of the head according to the condition age and character of his personages, and in making the different parts of every figure contribute to the general effect. His design also, like that of Raphael, was formed on the model of the ancients, but was, in general, more slender than the designs of Raphael. Contrary to the general practice of the French artists, he did not endeavour to astonish the spectator by shining contrasts, beautiful groups of figures, or the deceitful pomp of theatrical scenes. The tones of his colours are delicate, and his tints harmonious; and though not so attracting as those of the Venetians and Florentines, are yet engaging. They delight the observer, without diverting his attention from the more material parts.

The French school have reason to deplore the early loss of this artist, who might otherwise have obtained influence sufficient to have founded a new manner among that sect: the noble beauty of his heads, the simple majesty of his draperies, the correctness and airiness of his design, the propriety and justness of his expression and attitudes, and the simplicity of his general disposition, would, no doubt, have soon become the object of imitation; and Paris might have attempted to rival Rome in the productions to which such a manner must have necessarily given birth. The justness of these remarks appears in some of the best pieces of Le Sueur, namely, the twenty-two pictures he painted for the Carthusian monastery at Paris, his preaching of St. Paul, and the picture which he painted at St. Gervais; the latter has, by many able critics, been allowed to be equal to the best productions of the Roman school.

The German school is nothing more than a succession of single artists, who derived their manner from different sources of originality and imitation. The most early German painters were wholly unacquainted with the works of the ancients, and had scarcely access to those of their contemporaries in Italy: they, therefore, copied nature alone, somewhat divested of that stiffness observed in the Gothic manner. But the German artists of succeeding times were educated, some in Flanders and others in Italy: their manner has consequently nothing peculiar by which their works may be known. It is to the more ancient of this sect we must advert for a decided character. The manner of these, as before observed, displays more of the Gothic style than appears in the works of any other school. Albert Durer and John Holbein were the two principal of that nation. The former was the first who corrected the vitiated taste of his countrymen; he was a good engraver as well as an excellent painter; and finished his numerous works with great exactness. He possessed a fertile invention, a lively genius, an inexhaustible fund of thought, and a brilliancy of colouring. He is, nevertheless,

charged with stiffness in his outline, want of taste and grandeur in his expression, a neglect of gradation in his colours, and an ignorance of the costume of aerial perspective, though it must be acknowledged that he had closely applied himself to lineal perspective architecture and fortification. Holbein, contemporary with Durer, painted both in oil and water colours. He applied himself chiefly to portraits and historical pieces, in both of which he acquired fame. All his works are highly finished, and his colours are fresh and brilliant; but his draperies fall far short of those of Albert Durer.

The Flemish School possesses a conspicuous place in the history of this art, by the discovery, or at least the first practice, of painting in oil, by John Van Eyck, and his brother Hubert. This school is remarkable for its great brilliancy of colours, and a most enchanting display of the *chiaro oscuro.* In its design also we observe truth and justice, though the forms be not the most beautiful: it possesses a grandeur of composition, a certain air of nobleness in the figures, with a strong and natural expression. We observe a kind of beauty in the productions of this class peculiar to themselves, and which appears to be neither copied from the ancients, nor from the Roman nor Lombard schools. But this school, like that of the Venetians, upon which model it was formed, possesses too much locality. Rubens their head took his figures mostly from the people before him: and, as Paul Veronese introduced Venetian gentlemen into his pictures, in the same manner did Bassano delineate the boors of his district, and called them patriarchs and prophets. The founder of this school was John de Bruges; but Peter Paul Rubens must be considered as laying the foundation of the rationale of the art in that country. This indefatigable and excellent artist has left us numerous monuments of his various powers. He succeeded equally in portrait, landscape, and historical painting: he excelled also in fruits, animals, and flowers. His works appear less destitute of that soft inspiration which produces that pleasant effect felt on reviewing the works of Raphael; but he is still successful in producing astonishment in the observer. His figures appear to be the counterpart of his great conceptions. His design is noble and easy. Notwithstanding his great knowledge of anatomy, the impetuosity of his imagination, and his ardour for execution were so great, that he preferred splendour to the beauty of forms and symmetry; and too often sacrificed his correct taste for design to the magical illusion of colours. In his draperies he was rather *fine* than *pertinent,* for he justly considered that *clothing* and *drapery* are not synonymous terms. He is the first among painters for pomp and majesty; the first among those who speak to the eye; and the power of the heart is, by him, often carried to the highest pitch of enchantment.

Few, if any, artists invented and executed with greater facility than Rubens: he frequently made several sketches of the same subject altogether different from each other, without allowing any time to elapse between them, which at once indicates the variety of his conceptions, and his diligent application to the subject. It must be allowed that he excels chiefly in colouring, in which it is also evident he is surpassed by Titian. On a comparative view of Rubens with Titian, we may, without partiality, observe that Rubens' method was to lay the colours in their places one at the side of another, and blend them afterwards by a slight touch of the pencil. Titian mingled his tints to produce the

effect of natural colours, in such a manner as to render it impossible to discover where they began or terminated: the effect is evident, the labour is concealed. It is upon this account that Rubens appears more dazzling, and Titian more harmonious. The former excites the attention, the latter fixes it. The colours of Titian resemble those of nature; but those of Rubens the effect of art. The figures of Rubens act with energy, and indicate expression; but they are deficient in simplicity and dignity. His colouring is too much *tinted:* in a word, in all his works, there appears a want of that distinction and elegance of mind requisite in the higher walks of painting; nevertheless, all the qualities of the subordinate style appear in him with their greatest lustre. In his behalf we must admit, that the facility with which he invented, the richness of his composition, the luxuriant brilliancy of his colouring, so dazzle the eye, that, on a contemplation of his works, we readily excuse all his defects. Sir Joshua Reynolds observes, " Rubens is a remarkable instance of the same mind being seen in all the various parts of the art. The whole is so much of a piece, that one can scarce be brought to believe, but that if any one of them had been more correct and perfect, his works would not be so complete as they appear. If we should allow a greater purity and correctness of drawing, his want of simplicity in composition colouring and drapery would appear more gross."

The Dutch School appears deficient in several essentials of the art, except that of colouring. Their artists depart further from the great style than those of the Flemish school, by their slavish confinement to local manners and personages. They have also fallen lower, in this respect, than the Flemings, by not only disregarding beauty of heads and forms, but in singling out, for their imitation, the most low and ignoble objects, namely, tavern scenes, views of smiths' shops, and the vulgar amusements of the rudest peasants; nevertheless, in these the expression of the passions are sufficiently marked. The distinguishing characteristics of this school are a predilection for low and mean subjects; a success in the most striking parts of the *chiaro oscuro,* as in the display of light confined in a narrow space, as that occasioned by torches, a smith's forge, and moonlight scenes; a just observance of perspective; a successful description of clouds, sea scenes, animals, flowers, fruits, insects, &c. in miniature painting, and, in short, in every thing which requires a faithful imitation, good colour, and nice pencil.

The founder of this school was Lucas of Leyden, who flourished about the end of the fifteenth century; the subjects of his pencil were history, landscape, and portrait. He painted in oil, in water colours, and on glass. His picture of the *Last Judgment* is still preserved in the town-house of Leyden; it possesses a great portion of merit, and contains a great variety of figures. The Dutch school has produced some good history painters, in the persons of Octavus Van Been, and Vander Hilst; the latter the rival of Vandyke. Cornelius Polembourg may be considered as the father of miniature painting in this school; he possessed that delicacy of touch, truth of colouring, and disposition of the *chiaro oscuro,* which characterize all the miniatures of this class of artists; but he is too often incorrect in his design. The celebrated Rembrandt Vanryn degenerated more than any other artist of this school into that low grovelling choice of subject mentioned above, which is the more offensive in his productions, as they often require an opposite choice of figures. It is related of him, that he studied the grotesque appearance

of a Dutch peasant, or the servant of an inn, with as much application as the greatest masters in Italy would have studied the Apollo of Belvedere, or the Venus de Medicis. In this respect he deserves to have every indulgence shewn him: as his father was a miller, near Leyden, he was denied the advantage of a liberal education, and his success in the art depended entirely on the exertion of his own natural talents. M. Descamps observes, that "Rembrandt may be compared to the great artists for colour, and delicacy of touch, and *chiaro oscuro*. It appears that he would have discovered the art, though he had been the first person that ever attempted it. He formed to himself rules and a method of colouring, together with the mixture of colours, and the effect of the different tones. He delighted in the great oppositions of light and shade; and he seems to have been chiefly attentive to this branch of the art. His workshop was occasionally made dark, and he received the light by a hole, which fell as he chose to direct it on the place which he desired to be enlightened. On particular occasions he passed behind his model a piece of cloth of the same colour with the ground he wanted; and this piece of cloth receiving the same ray which enlightened the head, marked the difference in a sensible manner, and allowed the painter the power of augmenting it according to his principle.

"Rembrandt's manner of painting is a kind of magic. No artist knew better the effects of different colours mingled together, nor could better distinguish those which did not agree from those which did. He placed every tone in its place, with so much exactness and harmony, that he needed not to mix them, and so destroy what may be called the flower and freshness of the colours. He made the first draught of his pictures with great precision, and with a mixture of colours altogether particular: he proceeded on his first sketch with a vigorous application, and sometimes loaded his lights with so great a quantity of colour, that he seemed to model rather than to paint. One of his heads is said to have a nose nearly as much projected by the quantity of colour in it as the natural nose which he copied."

The distinguishing characters of Rembrandt are a surprising power of genius, which more than counterbalances all his numerous faults, and a just and lively expression, executed with great judgment.

The next artist of this class is John de Laer, a painter of miniature. He merits a considerable place in the Dutch school, from his correct manner of design, and vigorous and lively colouring. He did not descend so low in the choice of his subjects as most other artists of this class: his scenes were those of common life, and consequently displayed more nature than sublimity: they were chiefly hunting parties, the attacks of robbers, public festivals, landscapes, and sea views; and he ornamented his pictures with old ruins, and enriched them with figures of men and animals.

The last school to be mentioned, but which ought to possess the primary place in the estimation of the students for whom this work is intended, is The English School. This sect, founded in our own time, and in our own country, under the munificence of a prince, ever intent on promoting literature and the arts in every department; and under a director, of great solidity of judgment and delicacy of taste, cannot fail, under well directed precepts, to attain the highest degree of excellence. Its professed object is, in a word, to unite in itself, according to the

principles of true taste, the various excellencies which lie dispersed among all the other classes of painters. But to avoid the appearance of partiality of speaking of this school, its general character is here given from a French artist, from whom we can be in little danger of receiving unmerited praise:—"Beauty ought to be the characteristic of the English school, because the artists have it often exposed to their view. If this beauty be not precisely similar to that among the ancients, it is not inferior to it. The English school should also distinguish itself for truth of expression, because the liberty enjoyed in that country gives to every passion its natural and unbiassed operation. *It will probably long preserve its simplicity, unpolluted by the pomp of theatrical taste, and the conceit of false graces, because the English manners will long preserve their simplicity.* Examine the picture of a French woman, painted by an artist of that nation, and you will generally find, in place of expression, a forced grin, in which the eyes and the forehead do not partake, and which indicates no affection of the mind. Examine the picture of an English woman, done by one of their painters, and you observe an elegant and simple expression, which makes you at once acquainted with the character of the person represented."

This school was formed only in the year 1769. To bestow any encomiums on its founder (Sir Joshua Reynolds) would be superfluous. His works indicate a genius which has seldom been surpassed: and his discourses to the academicians, joined to his example as a painter, have disseminated, and will secure his reputation as long as England or the world at large, shall esteem the worth of great abilities.

Whoever examines the pictures of the English school; namely, the Death of General Wolfe, the Departure of Regulus for Carthage, the arrival of Agrippina, and some other subjects, cannot hesitate a moment to pronounce that this society is acquainted with true greatness of style, boldness of expression, and the art of managing a great number of figures. It is the wish of every lover of the arts, and fortunate it will no doubt be, for the fame of British painters, if the members of this class be more rigid in exactness, with regard to their forms, than solicitous to produce poignant and astonishing effects.

The taste of the English school appears to be formed on the great masters of the Italian and Flemish schools. Sir Joshua was a great admirer of Michael Angelo, and particularly recommends him to the attention of the academicians:—"I feel (says he) a self-congratulation in knowing myself capable of such sensations as he intended to excite. I reflect, not without vanity, that these discourses bear testimony of my admiration of that truly divine man; and I should desire that the last words which I should pronounce in this academy, and from this place, might be the name of *Michael Angelo*." But though he thus enthusiastically admired this very great man, yet he allows, what cannot indeed be denied, that he was capricious in his inventions:—"and this (says he) may make some circumspection necessary in studying his works; for though they appear to become him, an imitation of them is always dangerous, and will prove sometimes ridiculous. In that dread circle none durst tread but he. To me, I confess, his caprice does not lower the estimation of his genius, even though it be sometimes, I acknowledge, carried to the extreme: and however those eccentric excursions are considered, we must at the same time recollect that these faults, if they are faults, are such as never could occur to a mean and vulgar

mind; that they flowed from the same source which produced his greatest beauties; and were therefore such as none but himself was capable of committing; they were the powerful impulses of a mind unused to subjection of any kind, and too high to be controuled by cold criticism."

The greater part of the foregoing schools are now extinct. Italy alone had four schools, and at this time there remain but a few Italian artists known to foreigners. The school of Rubens in Flanders is no more. The Dutch school, if it still exist, is not known beyond the limits of that country: and not more than two or three artists remain of the German school.

The busy enquirer may discover a probable cause which gave to each school its peculiar manner. The purity and taste of the Roman artists are the natural consequences of the excellent education of the first masters of that school; and also of the precious remains of antiquity found in the ruins of that magnificent city. The gaudy taste of the Venetian school is owing to the richness and luxuriancy of those who only had it in their power to reward the artist, and whose vicious taste must be gratified at the expence of the real beauties of the art. The commerce of the East, and the consequently great population of the city of Venice, conspired to render the artist more conversant with tumult than rural scenes. And the frequency of feasts masquerades and public assemblies rendered these scenes objects of general attention. A similar cause operated in the Dutch school. The painters of that country, accustomed to visit taverns and workshops, acquired their low style from the frequency of those mean and grotesque figures they had constantly before their eyes.

On a comparison of the ancient with the modern practice of painting, the curious critics have found it difficult to decide the superiority. In sculpture the ancients undoubtedly excelled: but in painting it is more generally asserted (though perhaps not strictly true) that the Greeks are inferior. The chief difference of the two manners consists in the complication of figures, and the pompous decoration of scenery which prevail in the works of the moderns. The productions of the ancient painters are remarkable for unity and simplicity, which is evident is not the effect of incapacity, but of a decided choice. Polygnotus, one of their most ancient artists, painted the siege of Troy, and introduced also a great number of figures in his *Descent of Ulysses into Hell.* But two, three, or at the most four figures, were the greatest number admissible. Though too great a number of figures in a piece diverts and distracts the attention of the observer; yet, on the other hand, it must be admitted, that we are accustomed to behold assemblages in nature; and it is an undoubted fact, that in an affecting scene a great number of figures may not only be brought together, but may considerably heighten the distress. Upon a view of the matter, it appears, that the moderns have chosen a more difficult part; and if they have executed it with success, their merit is so much the greater.

But a more particular view of the subject will lead us to a consideration of the eminence of the ancient painters in the particular branches of the art. The only evidence on this head must be derived from the morsels of antiquity which yet remain, and from what ancient writers have said on the subject of painting, both of which are extremely defective. It is generally allowed by every skilful per-

son who has examined the former, that none of them appear the performances of superior artists, notwithstanding the merit in the design, and the accuracy in the drawing, which seem the characteristics of all the ancients. The best ancient painting, the supposed marriage, in the Aldrobandine palace, Sir Joshua Reynolds says, "is evidently far short of that degree of excellence undoubtedly implied in the descriptions of ancient artists, and which from them we are fairly led to expect." And of the many treatises which we are informed were composed by the ancients, on the subject of painting, not one work written expressly on the art remains. All we can collect is from a few desultory remarks, and cursory notices, dispersed in essays on other subjects. We are, however, by these sufficiently informed that the ancient artists paid particular attention to design, in which they were so successful as to become the models of, and still remain unequalled by the moderns. This is the less to be wondered at when we reflect that many of them united the art of sculpture with that of painting: it was the case with Zeuxis, Protogenes, Apelles, &c. And, from the antiquities of Herculanum, it is evident that many of their artists, even of mediocrity, far excelled the moderns in the truth elegance and spirit of their design.

The same cause, namely, their knowledge of sculpture, enabled them to succeed equally in expression, which is carried to such an unrivalled height, that in their statues we observe not only the conformity of every feature of the face to produce this effect, but every muscle in the body contributes towards this great perfection. Neither were they defective in the expression of characters and manners. Mr. Webb observes, "the ancients thought characters and manners so essential to painting, that they expressly term *picture* an art descriptive of manners. Aristotle also, in his poetics, says of Polygnotus, "that he was a painter of the manners;" and he mentions the deficiency of Zeuxis in this particular. Philostratus gives the following description of a picture:— "We may instantly distinguish Ulysses, by his severity and vigilance; Menelaus, by his mildness; and Agamemnon, by a kind of divine majesty. In the son of Tydeus is expressed an air of freedom; Ajax is known by his sullen fierceness; and Amilochus by his alertness. To give to these such sentiments and actions as are natural to their peculiar characters, is the ethic of painting. The Medea of Timomachus is also an instance of excellent expression."

We are not warranted in bestowing equal commendations on the colouring of the ancients; though there is no doubt but they particularly studied this part of the art, and arrived in it to a considerable excellence: but as the praises of ancient authors, on this head, relate chiefly to the style as exerted upon single figures, or particular tints, it may be doubted whether they possessed the art of distributing their colours, through the whole of the piece, so as to produce that harmony and general tone of colouring we admire in the works of the Lombard and Flemish schools. From the writings of Pliny, Lucian, and Plutarch, we may collect, that the ancient painters of Greece understood the rationale of colouring. Pliny mentions *tone* of colours, and the *handling*, or what we now call *harmony*. Lucian, in his description of the male and female centaurs by Zeuxis, after describing the treatment of the subject, proceeds to notice the technical execution of the picture; and he praises, in particular, the truth and delicacy of the drawing, the perfect blending of the colours, the skilful shading, the scientific preservation of size

and magnitude, and the equality and harmony of the proportions throughout the whole piece. Plutarch also observes, that "painters increase the effect of the light and splendid parts of a picture, by the neighbourhood of dark tints and shades." And Maximus Tyrius says, that "bright and vivid colours are always pleasant to the eye; but this pleasure is always lessened, if you omit to accompany them with somewhat dark and gloomy." These, and other testimonies, evince a knowledge of the use of dark and cold tints, even in a brilliant tone of colouring: but the best ancient painters appeared to have preferred a chaste and sober style to the more gaudy and fluttering one of later times.

Very good artists and eminent critics, among the moderns, have denied the ancients any knowledge of the *chiaro oscuro,* because it is not met with in any of those remains which have come to our hands. The Abbé du Bos, on the contrary asserts, that they equalled, in this part of the art, the most celebrated among the moderns; grounding his opinion on the assertions of Pliny and other ancient writers, concerning the delightful distribution of light and shade: it appears, however, on the examination of the greater part of the passages from antiquity, that the ancient painters understood at least what relate to the light and shade of single figures, without including what is now called the *chiaro oscuro.* The remains of ancient artists, which have come to our hands, are indecisive upon this subject, as they are the productions of an inferior class, and may be considered as on the same rank with the paintings that ornament our public gardens.

With regard to the art of grouping their figures, critics are generally of opinion that the ancient painters are far excelled by the moderns. In the remaining antiquities we meet with few examples of this most difficult branch: and among the many paintings enumerated by Pliny, Lucian, and Philostratus, none of them is praised for this excellence. From the paucity of the figures introduced into the generality of the ancient pictures there is no reason to expect that they attended much to this very material branch of the art: but there is sufficient reason to believe they were not, in this point, entirely destitute of taste: for in a picture found in Herculanum, which is thought to represent the education of Achilles, the figure of an old man holding a child on his knee, together with that of a woman behind him, form a very agreeable group. Another work, in the same collection, painted in one colour, on marble, consists of five figures, grouped very much after the modern idea, if it were not that three of the heads are of the same height. This piece is, most probably, the copy of a picture finished in the purest times of Greece. And one of their paintings, mentioned by Pliny, is said to have contained one hundred figures, which unwieldy number must produce a very disagreeable effect, if they were not grouped with some skill. Perhaps their inattention to this quality arose from their peculiar taste. Desiring to display, in the fullest manner, their painted figures, as they did their statues, they detached every figure from another in the same picture, by which means they were enabled, not only to give their objects more relief, but to render them more distinct and apparent to a distant observer.

With regard to invention, there is little doubt but they were at least equal to the moderns, : many instances might be adduced in support of their claim to this merit: but it will be sufficient to observe, that as they

have far surpassed the moderns in invention, in the two sister arts, namely, poetry and sculpture, there is no reason to believe they fell short in that of painting. As a happy invention also is rather a natural endowment than an acquired talent; and as the ancients seem in no wise inferior to the moderns in the gifts of genius and good sense, we cannot hesitate a moment in assigning them the honour of possessing this branch of the art.

On examining their works with a view to trace their observance of the *costume*, or that attention to probability with respect to time, place, objects, persons, and circumstances, we find the most gross violations of probability and representations of events, impossibly coincident. This has given occasion to some critics to assert, that the ancients knew nothing of, or at least did not attend to the costume; but this charge is brought somewhat too hastily: for those productions are evidently the performances of artists of no reputation; and none of them to which this objection implies are regular representations of any person or transaction; they were likewise, for the most part, manifestly intended as ornaments to apartments, and as such were of an inferior class of painting; the taste of the owner, likewise, and not that of the artist, was consulted.

From the manner in which the ancient writers expressed themselves on this subject, not recommending the practice of it, but taking it for granted, we may conclude that their best painters seldom violated this rule. Perhaps the ancients attended more scrupulously to the costume than the moderns: for the most celebrated of modern painters, from Raphael to Sir Joshua Reynolds, have departed so widely from this rule, in many instances, as to shock the sober reason of a person not aware of them.

Concerning the attention of the ancient painters to the rules of perspective,, they would fall under the same censure as when examined touching their knowledge in the *chiaro oscuro*: that is, if we decide upon them, in this particular, from a view of their works, we must pronounce them more ignorant or careless of its laws than an English sign painter. Such flagrant violations of the rules of perspective appear in the picture of the Sacrifice, among the Herculanean antiquities; and the fourth of the pieces taken from the paintings in the sepulchre of the Nasones, as to indicate some little knowledge of perspective in the artist; but in the other landscapes of the ancients, we see so little observance of its laws, that we cannot dwell on the comparison. But a knowledge of this essential rule, and, no doubt, a perfect mathematical skill in its precepts, cannot be denied them. They were good mathematicians, they were excellent architects, and some of them are celebrated for their skill in scene-painting. The ancients also practised the art of painting in perspective on walls, in the same way that it is now done by the moderns: and Pliny says that one of the walls of the theatre of Claudius Pulcher, representing a roof covered with tiles, was finished in so masterly a manner, that the rooks, birds of no small sagacity, taking it for a real roof, attempted to light upon it. We are likewise told, that a dog was deceived to such a degree, by certain steps in a perspective of Daulos, that expecting to find a free passage, he made up to them in full speed, and dashed out his brains. But what is still more, Vitruvius tells us, in express terms, by whom, and in what time, this art was invented. It was first practised by Agatharchus, a contemporary of Æschylus, in the theatre of Athens; and afterwards reduced to certain principles, and

treated as a science by Anaxagoras and Democritus; thus faring like other arts, which existed in practice before they appeared in theory. Thus it appears that the ancients were not inferior to the moderns in all the principal parts of the art; in the drawing and colouring of single figures, they must be allowed to be equal, if not superior, to the moderns; their statues and paintings remaining, evince the spirit, animation, ease, and dignity of their manner: as they possessed all the requisites of portrait painting, it is no wonder that they excelled in that branch. The purity of their design, and beauty and expression of their forms, laid the foundation of excellence in modern artists. Those parts of the art in which they are excelled by the moderns, are the inferior qualities; the allurement of colouring, the ingenuity of the *chiaro oscuro,* the splendour of composition, the art of grouping figures, and the nice handling of the pencil. He who imagines that all the qualifications necessary to form a good painter are circumscribed within the mechanical management of colours, and a knowledge of the *chiaro oscuro,* does very little justice to the art of painting, and will, in the end, find himself greatly deceived. The success of some eminent men, who were in a great measure, unacquainted with every other subject but that of painting, by no means warrants the hasty, crude, and unqualified attempts of others; on the contrary, their frequent failures should serve as beacons to guard us from the like mistakes, and caution us from pursuing this subject with minds unfurnished with the requisite materials. Though the artist do not require that extensive knowledge which Cicero says the orator should possess; yet there are many subjects, his acquaintance with which is indispensable to insure his success. The principal of these are anatomy, perspective, a general knowledge of sacred, civil, and fabulous history, and an attentive observance of nature. To insist upon the necessity of this branch of the student's attainments would be superfluous: the authorities and examples of the greatest masters and most celebrated schools are sufficient to enforce the prosecution of this subject. He who is unacquainted even with the form and construction of the several bones which support and govern the human frame, and who knows not the offices and situations of the muscles by which the bones are moved, will never be able to describe accurately those variations they occasion in the exterior surface of the body, a delineation of which is, however, the noblest part of the art. It is impossible for the painter to copy an object placed before his eyes unless he thoroughly understand it. Though he bestow ever so much time and pains on the subject he will not succeed; but, like him who undertakes to translate a work which he does not understand, from another language into his own, will only expose his own ignorance. The artist who expects to excel must be able also to describe, with justice to anatomical truth, the various parts of the human frame, under any sudden gestures, violent motions, and those momentary attitudes, in which he can procure no living model for a pattern. Here he will find occasion for an intimate acquaintance with anatomy. In still and languid positions, where the muscles are to have no action, a living model may afford him considerable assistance, and for a long time furnish him with a faithful pattern: but, in the former case, postures and attitudes may be required, wherein a living model cannot remain above a minute or two, and then grows languid and settles into a fixed attitude. The painter must, therefore, acquire such knowledge of anatomy as to be able, at all times, to express his subject in every

circumstance and situation. Though copying from living models has been practised by the greatest masters, and still affords great assistance to the student, yet they very often mislead him, and tend to make him lose sight of truth and nature, by exhibiting the very reverse of what is required, or displaying it in a faint and imperfect manner. For in living bodies we often observe a coldness and torpidity in those parts which should have the greatest share of life and spirits; and where there should be a quick motion we perceive a slow one, and *vice versa.* It is not to be understood, from what is here advanced, that the student is to enter as deeply into the subject of anatomy as the surgeon or physician. It is enough for him to be acquainted with the skeleton; or the form and connection of the bones; and the origin, insertion, and use of each of the principal muscles, with their general appearance when in action. In conjunction with the study of anatomy, and as assistant thereto, he should, if possible, have recourse to anatomical casts. There are many very good ones extant, the productions of men every way adequate to the subject.

Perspective claims the student's attention equally with anatomy. The latter enables him to express the human body, and its various parts, in every situation and circumstance: the former teaches him to give objects their respective contours, according to their distances from the observer, and their relative situations. For the contour of any object, drawn upon a plain surface, is nothing more than such an intersection of the visual rays, sent from the extremities of the object to the eye, as would appear on a glass, put in the place of the canvas or paper, upon which the object is drawn: the surface, therefore, of the picture may justly be considered as no other than a glass through which we perceive the object on the other side of it. Consequently the situation of an object on the one side of a glass being given, the delineation of it on the glass itself depends entirely on the situation of the eye of the observer on the other side of the glass; that is to say, on the rules of perspective. How necessary the knowledge of this art is to a painter a very little reflection will determine. It teaches in what proportion the parts of an object lessen from the eye, according to their distances; and how figures are to be marshalled and foreshortened upon a plain surface: in a word, it contains the whole principles of design. Notwithstanding the utility of this art, it has been too much neglected by many modern painters, who have considered it as extending no farther than to the painting of scenes, floors, &c. it has even been called a fallacious art, and an insidious guide: but those best acquainted with it can demonstrate the incontrovertible truth of its principles, which are founded on the most evident laws of geometry; and the greatest painters are sensible, that without its assistance it is impossible to describe with justice a simple outline. But as perspective is founded upon geometry, and depends for its demonstration on the doctrine of proportions, on the properties of similar triangles, and on the intersection of planes, the student should possess a general knowledge of geometry.

Nearly allied with perspective and geometry is the knowledge of optics, with which the painter must be well acquainted. Having but a slight knowledge of geometry and perspective he will find optics an easy task. Its laws, like those of perspective, are founded on lines and angles. Any treatise on the subject, containing the general laws of vision, reflexion, and refraction, will be sufficient for his purpose. It will teach him to

determine the degree in which objects are to be illuminated, or shaded; it will enable him to cast the shades of his figures properly on the planes on which they stand; and, in general, furnish him with the whole rationale of the *chiaro oscuro*. Amidst his other necessary qualifications, the young artist must by no means neglect the study of nature. The artist must be fully sensible, that by the term *following nature*, he is by no means to understand a servile manner of copying natural objects. Painting is not only to be considered as an imitation operating by deception, but it is, strictly speaking, in many points of view, no imitation at all of external nature; but is as far removed from the vulgar idea of imitation as the refined civilized state in which we live is removed from the rude unpolished manners of the Hottentots; and those who have not cultivated their minds by an attention to the rules of taste, may be said to continue, with regard to their intellectual powers, in a state of nature. Such people will always prefer crude unqualified imitation to the other higher excellencies, which are addressed to faculties they do not possess: but those are not the persons to whom a painter is to look, and from whom he is to expect reward. His productions, to possess immortality, must deserve the attention of the enlightened part of mankind: I mean those only who are taught to renounce the narrow idea of nature, and the narrow theories derived from that mistaken principle of copying her servilely, and in the detail. In the higher parts of both poetry and painting a servile imitation of nature is strictly to be avoided. A higher order of beings is to be introduced into the piece, to whom every thing else must correspond. Steen, in his picture of the Sacrifice of Iphigenia, has rendered both himself and the subject ridiculous, by his slavish confinement to individual nature: notwithstanding there is great expression in his figures, and probability in the composition, yet it is such expression, and the countenances are so familiar and vulgar, and the whole company attired with such a finery of silks and velvet, that a great artist was tempted to doubt whether the painter did not purposely intend to burlesque the subject. "If we suppose," says an eminent painter, "a view of nature, represented with all the truth of the *camera obscura*, and the same scene represented by a great artist, how little and mean will the one appear in comparison of the other, where no superiority is supposed from the choice of the subject. The scene shall be the same, the difference will be only in the manner in which it is presented to the eye. With what additional superiority then will the same artist appear when he has the power of selecting his materials as well as elevating his style? Like Nicholas Poussin, he transports us to the environs of ancient Rome, with all the objects which a literary education makes so precious and interesting to man: or, like Sebastian Bourdon, he leads us to the dark tranquillity of Arcadian scenes and fairy land. Like the history painter, a painter of landscapes, in this style, and with this conduct, sends the imagination back into antiquity; and, like the poet, he makes the elements sympathise with his subject: whether the clouds roll in volumes, like those of Titian, or Salvator Rosa;—or are gilded with the setting sun, like those of Claude Lorraine; whether the mountains have sudden and bold projections, or are gently sloped; whether the branches of his trees shoot out abruptly, in right angles from their trunks, or follow each other with only a gentle inclination. All these circumstances contribute to the general character of the work, whether it be of the elegant, or of the more sublime kind.

"If we add to this the powerful materials of light and dark over which the artist has complete dominion, to vary and dispose them as he please; to diminish or increase them as will best suit his purpose, and correspond to the general idea of his work: a landscape thus conducted, under the influence of a poetical mind, will have the same superiority over the more ordinary and common views, as Milton's *Allegro* and *Pensieroso* have over a cold prosaic narration or description; and such a picture would make a more forcible impression on the mind than the real scenes, were they presented before us." Thus it appears that an artist should have a mind enlightened with a general knowledge of science; but this is not sufficient: he should be acquainted both with historical facts and the principal epic histories. Those who imagine that a painter stands in need of nothing more than a few casts of the remains of antiquity, with some other relics, are greatly deceived. Algarotti observes, that such things are, no doubt, necessary to a painter, and perhaps for one who wants only to paint half lengths, or is willing to confine himself to a few low subjects. But they are by no means sufficient for him who would soar higher; for the painter who would attempt the universe, and represent it in all its parts, such as, in our imagination, we think, not unreasonably, it might appear, such a painter alone is a true, an universal, a perfect painter. And though none can expect to attain this high degree of eminence, yet all should aspire towards it, on the pain of ever continuing at a very mortifying distance from it. It is necessary to have this idea of a perfect painter in our mind, as a pattern to excite emulation. Without some such incentives the mind would degenerate into torpidity; the artist would doze over his work; and go on copying without improving, and painting but without success.

Of Painting in Oil: the necessary Materials, and Method of Using them.

Of every part of the fine arts, painting in oil, undoubtedly, claims the pre-eminence: it exceeds every other species of painting in its greater accuracy of colours, and in its wonderful force and expression. It also surpasses miniature and crayon painting, in its extended dimensions, whereby most objects of animated nature may be represented as large as the life, by which means the imitation is rendered more complete, and the powers of illusion and deception perfected, to such a degree as to astonish the inexperienced in the art. But these are only the inferior qualifications of an artist; the skilful painter possesses higher excellencies, and aims at far nobler attainments.

The materials necessary in oil painting are, a pallet, a pallet-knife, pencils, tools, an easel, picture cloths, a maul stick, and oil colours. The *pallet* is so common as to need no description: its use is to contain the colour, being held on the left hand while at work, by passing the thumb through a hole near the front. *To set the pallet*, signifies the placing of the colours thereon in their proper order. The middle of the pallet serves to hold the colour while it is wrought with the pallet-knife, with the addition of some nut oil, if necessary. The colour is then put in its proper place on the pallet; that is, the lighter colours are placed next the hand, the darker ones next, increasing in the depth of their colours in proportion to their distances from the front of the pallet: a second row of tints is then to be formed of the original colours, by mixing these

together, in such proportions as to produce tints to suit the subject of the piece. A third row of tints must also be made, which should, if possible, approach nearer the complexion of the piece than the second row. For example, the original colours being placed on the outer part of the pallet, take lake and Naples yellow, to which white may be added; this composition forms the second row. If a lighter tint of the same colours be wanting, an addition of white will produce it, to form the third row; or a light red, or a light yellow, to the colours of the second row will also form the third row; or any other variation, as may suit the artist's intention. The oil colours are best kept in bladders; and when wanted for use the bladder is to be pricked with a pin, and no more colour squeezed out than is necessary for the present use, otherwise it will spoil. The *pallet-knife* is a thin well-tempered blade: its use is to mix and work up the colours on the pallet. *Pencils* are generally of two sorts, viz. camel-hair pencils and fitch pencils. Fitch pencils are used by some artists to give a smoothness to their pictures, by working the colours into each other after they have been laid on with the camel-hair pencil. This is called *scumbling the colours.* Others, who wish to give a bold appearance to their works, paint wholly with fitches. *Tools* are only a larger kind of pencils, not inserted into quills, of the foregoing; but the hairs are bound round a stick, in the manner as the brushes used by house-painters. They are of a stronger nature: some good artists have used no others. There is also another sort of pencils, having very long hairs, used chiefly by painters of shipping, to describe the ropes, &c. The *easel* is formed various ways, according to the fancy of the artist. Its use is to support the picture, or canvas, upon which the painter is employed. The most common form for it is three strait legs, the longest being behind. In the two front legs are a number of holes, corresponding in height to each other, in order that, when a peg is placed in the corresponding holes of each leg, they support evenly whatever is laid upon them. A slight piece of board is usually placed on these pegs to support small pictures. *Picture-cloths* are those substances upon which the picture is painted. They were formerly almost universally of canvas, but some artists, of late, prefer a sort of ticking made for the purpose. Landscape painters generally choose cloths of a very smooth surface.

A *maul-stick* is a slender rod of wood, with a ball of cotton or some other soft substance tied to one end, whereby it may rest against the picture without damaging it. Its use is to support the right hand while at work, being held in the left hand with the cotton ball resting against the painting. This implement is not in universal use: many artists wholly reject it, as being pernicious to that freedom of hand necessary to a good painter.

Oil colours are so called because mixed with oil, as water colours are with water, no others being proper for this branch of painting. Many substances have been discovered by the moderns which answer the intention of the artist; the chief of those in general use, and from which all the variety of tints may be produced, are the following:—*Whites.*—Flake-white, and Nottingham-white. *Yellows.*—Yellow-ochre, Naples-yellow, King's-yellow, &c. *Reds.*—Carmine, Lake, Indian-red, Light-red, Vermilion, Red-lead, &c. *Greens.*---Terre-verte, Verdigris; but the best greens are formed by a mixture of blue and yellow, in different proportions. *Browns.*—Cologne-earth, Brown-pink, Umber, and Terra

de Sienna: the two latter are used both raw and burnt. *Blues.*---Prussian-blue, Ultramarine, and Verditer. *Blacks.*—Blue-black, and Ivory-black. Any other colour, and its various tints, may be formed from two or more of the foregoing. Green, as before observed, is produced by the union of blue and yellow, observing that the blue be not too deep, if it is, it will form a very dull green. The more blue there is in the composition, the darker will be the green; and, on the contrary, a greater quantity of yellow makes a lighter green. *Orange-colour* is formed by the mixture of a bright red and yellow. More red makes it darker, and more yellow lighter. *Flesh-colour* is compounded of red, yellow, and white, mixed in various proportions, according to the tint required. For a more florid complexion less white should be used; while a pallid countenance requires more white, and a swarthy complexion should have a tint of yellow-ochre. *Purples* are formed of blue and a bright red. If they be produced from a blue and a dark red, some white should be added. *Violet-colours* may be produced from the same colours as purple, but in violet the red must predominate more than in the purple, whose predominant colour is blue. *Ash-colour.*---By a mixture of black and white. *Bay-colour.*---A bright red with a little brown and black; as, for instance, vermilion with a little umber and black. *Carnation-colour.*---Red and white. *Crimson.*---The same as the last, but with a greater proportion of red. *Flame-colour.*---A bright red and full yellow. If the red be not bright a little white must be added. *Hair-colour.*---A light and dark yellow, united with brown, black, and white. *Lead-colour.*---A deep blue and white. *Russet-colour.*---Black and white. *Scarlet.*---A dark and light red. *Pink.*---A light red with a little white and yellow. *Sea Green.*---Yellow, with a small proportion of light blue. *Sky-colour.*---Light-blue and white; but in general a sky requires three tints: for the lowest parts light yellow, and white; for the next higher part blue and white; and for the upper part blue alone. *Straw-colour.*---A light and dark yellow, with a small proportion of light red. *Water-colour.*---Blue and white, heightened with white, and shaded with blue.

The above directions, well understood, will enable the student to form any other tint he may require. He must always remember, that white mixed with any colour, or with any composition of colours, always makes them lighter. But if any colour or tint be too light, it can never be rendered deeper by the addition of black: this would perfectly spoil it. And the best way to deepen a colour or tint when too light, is to paint it over with a darker colour of a similar nature, till it be brought to the tone required: this is termed *glazing it over*: and is also used where great richness is required in any particular colour, as in crimson, &c. in which case, when the crimson colour is laid on and finished, the artist glazes it with a coat of lake. Sometimes the picture, or a part thereof, is glazed twice or more, and the lights retouched: by repeated glazings with carmine and lake a bright white has been turned into a crimson. Glazing should always, if possible, be performed with transparent colours. It is, however, a practice not universally adopted, and seldom performed, by artists whose skill enables them to produce an equal effect without it. To heighten a colour it should be mixed with any similar colour of a lighter tone, as light red upon dark red; yellow upon light red; white upon yellow, &c. which is preferable to heigtening the colours with white only. The oils with which the co-

lours are mixed are of more importance in the art than is generally imagined. From their quality and their intimate mixture with the colour, by which they form, as it were, a part of the colour itself, they cannot but have a very great influence on the success of the piece. Those in most general use are linseed oil, nut oil, and poppy oil. *Linseed oil* generally injures light colours; its use therefore is, or should be, confined to the darker ones: some artists, to render it more transparent, rectify it, by exposing it in a bladder to the sun; but others wholly reject it. *Nut oil* is in more general use; it is more transparent than linseed oil; of a finer quality, works smoother, and is not so subject to change the colours. *Poppy oil* is generally preferred to the two others, as possessing all the good qualities of the nut oil, but in a higher degree: it is also clearer than the nut oil. To pictures painted in haste; and to preserve others from the injuries arising from the dampness of the weather, *drying oil* is sometimes used, which is formed by boiling some sugar of lead or litharge, in linseed oil. Drying oil should, however, be used with caution, and that only when indispensable; as those subjects where it has been admitted are generally found, in a short time, to have the appearance of old, and sometimes of decayed paintings. Though it be absolutely necessary, in many cases, to mix two or more colours together to produce a desired tint, yet the student must be cautioned against too wantonly indulging himself in the mixing of colours; for it is an undoubted fact, that the more simply the colours are used the easier they work, their appearance is brighter, and they are far more durable than a compound colour. For if a permanent colour be mixed with one that is not lasting, the latter destroys the durability of the former. And of those colours which are formed by composition, as green, orange, purple, and the like, that which contains the fewest ingredients is the best. Oil colours afford the artist an advantage which the painter in water colours can never possess; namely, that of retouching any part, or even the whole of his work; thus, black may be recoloured white, brown, or any other colour: but this practice is by no means recommended. It is never followed but when indispensable; for the undermost colour, to produce harmony and force, should have some affinity in its tone with the colour laid over it, which circumstance is not always to be expected. The cloth or canvas, upon which the picture is to be painted, is generally first primed. The priming is no more than laying on a smooth coat of colour. It is not of any great consequence what particular tint it is formed of, provided it is rather light than dark. Portrait painters choose a very thin priming: and many modern artists, whose works have met with general approbation, do not prime their cloths at all. The colours are then to be laid on in their proper places; after which they are sometimes softened into each other with a clean tool: this operation or scumbling, is not beneficial to every picture: where strength is required it should not take place, neither should it be used in the finishing touches. With regard to the progress of a picture no rule can be given that will universally serve to direct the student, scarce any two masters observe the same mode of procedure: the judgment is the principal guide: and, however two artists may vary from each other in the order of performing their work, they, in the end, produce the same effect as if they had both strictly followed one determinate rule. The only general method that can be recommended is the following:—The outline of the figure must be faintly sketched with white chalk, and af-

terwards more correctly formed with the pencil, and any thin transparent colour. The larger parts are next to be laid in with their proper colours, lights, and shades; which will, by degrees, produce an effect, or give the appearance of a whole. This may be called the first plan of the work, and should have more than ordinary care and pains bestowed upon it. At this period the colours should be carefully examined and compared with each other: their future relations and effects may now be foreseen. The next operation consists in bringing the different colours to their proper and respective tones. Some must be heightened, others kept down, and others again receive tints of different hues from what they possessed at first. The piece now begins to possess some harmony of colouring. In this stage the work is said to have gone through a second plan. The next and third process consists of the finishing part: force and relief must be added where wanted; a freshness of tint given to the carnations, as they are called, or flesh-colour, to produce accurate keeping; and a few smart touches must be added to conceal the effects of labour, particularly where much pains have been taken with the subject. All large shadows should be nearly of the same tone, according to their situations; smaller ones are somewhat fainter; and they should all be very thin of colour: the lights of the picture should be bold, distinct, and spirited, and should not want for colour, which renders them more permanent. The artist should always consider the distance at which his piece is to be viewed; for whatever produces no effect in the situation where the picture is to be placed is labour lost. Those paintings, therefore, which are to be placed in high situations; and also very large pieces, which must consequently be viewed at a considerable distance, should have no very minute work, which would not only be lost upon the observer, but, perhaps, by being viewed at a distance, and losing its intended effect, have an awkward and unpleasant appearance. Landscape painters generally begin their work about the centre of the piece; they paint the sky first, and gradually advance from the distant objects to the fore-ground. The backgrounds of all objects being treated first before the object itself; whereby a great deal of trouble is saved, which would be occasioned by painting round the objects. The following cautions and observations should be carefully attended to by the student:—If a tint be required, while he is at work on a picture, different from any on his pallet, it is better to mingle the colours which compose it on the pallet with the knife than with a pencil, as the pencil always retains more of one colour than another, when it is used to incorporate them together, and thereby the colour, with a little working, assumes a different hue. One pencil should always be kept to one colour, otherwise the colours will never appear fresh. Colours should never be teased, that is, mixed too much, or when, instead of being laid on the canvas at once, they are too much worked about with the pencil. This always injures them, particularly the lighter ones, and makes them lose their brilliancy and just effect. A proper allowance must always be made for that gloss and brilliancy oil colours possess while wet. The decay of colours is, in a great measure, the consequence of too great a quantity of oil: the parts of a picture which first begin to fade are the darker colours, the glazing, and where the colour is thin; but the lights stand much longer. It is always proper to permit a first coat of colour to be sufficiently dry, before a second is applied. To ascertain when an oil picture is dry, it

must be breathed upon pretty strongly, and if it take the breath it is dry. The pallet and pencils, when laid by, should be constantly cleaned with spirits, or oil of turpentine.

Of Imitation. Imitation is the first step and leading principle of the art of painting. It is a very necessary enquiry, therefore, for the young student, whom or what he should imitate, and how far the imitation should be pursued.

The grand object of the painter's imitation is that inexhaustible and ever varying source of beauty, *nature;* she should ingross the greatest share of his attention; and he must take her for his model, in her most singular effects, in her best tempers, and in her best attire. Nature, is not to be understood to be more perfect than art, which imitates it. It is confessed she offers some views, of which the imitation must for ever remain imperfect; as in the instance of a *chiaro oscuro;* but on the other hand, in every thing relative to beauty of form, imitation may surpass nature. Natuıe, in her productions, is subject to many accidents. Art, labouring on passive and obedient materials, renders perfect the objects of its creation; chooses every thing in nature the most excellent; and collects the different parts, and the different beauties, of many individuals into one whole. It is seldom that we find in the same man greatness of soul, and the due proportions of body; vigour of mind, suppleness, firmness, and agility of limbs, joined together. Art constantly represents what is rarely, or never to be met with in human nature; regularity in the outlines, grandeur in the forms, grace in the attitudes, beauty in the members, force in the breast, agility in the limbs, address in the arms, frankness in the forehead, spirit in the eyes, and affability over the whole countenance. Let an artist give force and expression to all the parts of his subject; let him vary this force and expression as different circumstances make it necessary; and he will soon perceive that art may surpass nature. But though this be granted, the artist is not to imagine that art is actually arrived at this supreme degree of perfection, and can proceed no farther. The moderns seem never to have perceived the tract pointed out by the ancient Greeks; for since the revival of painting, the true and agreeable, instead of the beautiful, have been the objects of cultivation. To avail himself of all the beauties of nature the artist must omit no opportunity of furnishing himself with a variety of sketches, of natural and even artificial objects, which possess any thing beautiful or striking enough to arrest his attention. For this purpose he should never be without his little book and crayon in which he may slightly pourtray the effect of any beautiful or interesting object or scene. Every fine building, every new effect of light, every novel arrangement of a flight of clouds, every flow of drapery, and every attitude and expression that possesses merit, should be carefully noticed. These sketches may not only furnish him with objects and scenes for his work, but he may derive a far greater benefit from them: the habit of selecting the beautiful parts of nature, and making them a whole, will greatly improve his taste, and expand his mind to the purpose of his art. In addition to the imitation of nature he must make himself well acquainted with the different styles of the most eminent masters, which he should attentively compare together, and examine. But he must be particularly careful to avoid a servile imitation of any of them. He must learn to admire their works, without imitating their manner. His imitation must be

general, and not particular. Whatever may be the natural bent of his own genius, he should follow it in preference to the manner of any other artist. Whether he choose to paint boldly and freely like Rubens, or to labour his works like Titian or Da Vinci, let him follow it; otherwise as the latter artist has observed, he will not be the child, but the grand-child of nature. The artist has also the liberty of imitating any antique, or even a modern figure, if it answer his purpose. This has been the practice of the most eminent in the art; and their pieces have not, upon that account, experienced the least derangement in their value. The addition of other men's judgment, is so far from weakening our own, that it will fashion and consolidate those ideas of excellence which lay in their birth feeble, ill-shaped, and confused; but which are finished, and put in order, by the authority and practice of those whose works may be said to have been consecrated, by having stood the test of ages. When we speak of the habitual imitation and continued study of nature, it is not to be understood that we advise any endeavour to copy the exact peculiar colour and complexion of another man's mind; the success of such an attempt must always be like his who imitates exactly the air, manner, and gestures of him whom he admires. His model may be excellent, but he himself will be ridiculous; and this ridicule arises not from his having imitated, but from his not having chosen the right mode of imitation. It is a necessary warrantable pride to disdain to walk servilely behind any individual, however elevated his rank. The true and liberal ground of imitation is an open field, where, though he who precedes has had the advantage of starting before you, yet it is enough to pursue his course: you need not tread in his footsteps; and you certainly have a right to outstrip him, if you can. The great use of studying our predecessors is to open the mind, to shorten our labour, and to give us the result of the selection made by those great minds, of what is grand or beautiful in nature; her rich stores are all spread out before us; but it is an art, and no easy art, to know how or what to choose; and how to attain, and secure the object of our choice. Thus the highest beauty of form must be taken from nature; but it is an art of long duration, and great experience, to know how to find it. He that is forming himself must look with great caution and wariness on those peculiarities, or prominent parts, which at first force themselves on view, and are the marks, or what is commonly called the manner, by which that individual artist is distinguished. Peculiar marks are generally, if not always, defects, however difficult it may be wholly to escape them. Peculiarities, in the works of art, are like those in the human figure; it is by them that we are cognizable and distinguished one from another; but they are always so many blemishes, which, however, both in the one case and in the other, cease to appear deformities to those who have them continually before their eyes. In the works of art, even the most enlightened mind, when warmed by beauties of the highest kind, will, by degrees, find a repugnance within him to acknowledge any defects; nay, his enthusiasm will carry him so far as to transform them into beauties and objects of imitation. It must be acknowledged, that a peculiarity of style, either from its novelty, or by seeming to proceed from a peculiar turn of mind, often escapes blame; nay it is sometimes striking and pleasing; but it is vain labour to endeavour to imitate it, because novelty and peculiarity being its only merit, when it ceases to be new,

it ceases to have value. A manner, therefore, being a defect; and every painter, however excellent, having a manner, it seems to follow, that all kinds of faults, as well as beauties, may be learned under the direction of the greatest authorities.

Of Colouring. Though *colouring* properly belong to the mechanism of painting, and is undoubtedly an inferior qualification, yet, as it is that peculiar property which immediately distinguishes it from the other imitative arts, it is evident it deserves the student's particular attention. Composition, imitation, design, expression, &c. are common to all the arts: but colours are, in a great measure, the principles upon which painting depends for its successful imitation. They impose upon the eye of the observer by their resemblance to natural colours: the more, therefore, they imitate those colours the greater is their success.

The reasons why so few painters succeed in colouring are, the great variety of the colours of natural objects; and the different capacities of men to distinguish them: we seldom perceive two flowers, or even blossoms, exactly of the same tint. And still more various are the opinions of mankind with regard to the gradations and combinations of colours, and that in proportion to the perfection of their visual powers and correct habit of judging, from being long accustomed to view tints of different hues. To excel in this branch, the student should make himself acquainted with that part of optics in particular, which treats of light and colours: otherwise he will never be able to account for many phœnomena of colours which he will observe when he comes to examine the properties and effects of different tints. In the pursuit of this subject he will find that light, simple as it may appear, is a composition of seven different rays, namely:—red, orange, yellow, green, azure, indigo, and violet. Experimental philosophy can ascertain the proportional quantity of each of these coloured rays to form a light; and can also demonstrate the truth of the assertion by decompounding a ray of light through a prismatic glass, whereby it, however small, is divided into its original primitive colours. (See Optics, p. 78.) Notwithstanding the great success of Titian, Coreggio, Giorgione, Vandyke, and a few others, who were little instructed in the physical subtleties of colours, no modern painter should presume to hope for an equal share of excellence, until he be acquainted with those causes in the science of optics, which produce the various effects of colours. Some minds, it is true, will surmount all difficulties, and dive into the hidden secrets of nature, unassisted by external aids; a natural, but rare sagacity, supplying and superseding other assistance: but great excellencies are generally the reward of long and indefatigable labour. Few men are by nature favoured with the discernment of a Newton, the judgment of a Locke, or the hand of a Titian. The power also of being able to assign the causes of the effects produced by our labour, is a pleasure sufficient to instigate any person to apply himself to this, as well as to the other branches of useful knowledge, in any manner connected with his pursuits. As it is impossible the painter can perfectly imitate any thing which he does not thoroughly understand, so it is almost, if not wholly, impracticable for him to display objects in their proper colours, till he know the causes by which those colours are produced, and how they are more or less altered by their various reflections on each other. Having attained this most essential requisite, the young painter must next study the works of the best colourists: there he will find his only rules to enable him to

express the beauty of objects, as far as relates to their colours. Titian and Coreggio seem to have been furnished by nature with the power of distinguishing colours, and their various tints, in a manner superior to all other artists; and thus, consequently, attended to circumstances in their work, rejected by both their predecessors and their followers. The former, as he did not handle his pencil, so he does not appear to have viewed his objects in the manner of other artists. His works display that sweetness of colouring produced by union; that beauty inseparable from truth; and all those insensible conversions, soft transitions, and pleasing modulations of tints and colours, we observe in the productions of nature. The lustre and transparency also of the pièces of the Flemish school, which give them a most enchanting appearance, may furnish him with some useful hints; though it must be confessed, they are chiefly the effect of varnishes. They are, however, not without their use, as they serve to shew how far colours may be improved by these additory articles. Two cautions are absolutely necessary to the young painter, while studying the works of those great masters. He should be careful that the pieces he selects for his models have been well preserved. There are none but have suffered, more or less, from the injuries of time; though time only is capable of giving them that beautiful *patina* or crust which at once renders them valuable, and stamps their antiquity; and though this produces that extraordinary degree of harmony in the colours, and takes from them their rawness, yet, on the other hand, it somewhat destroys their lustre, impairs their freshness, and detracts from the life of the piece: for an old picture, though it may have been carefully preserved, appears much as it would do immediately after painting behind a dull glass. He must also make due allowances for the ravages of time: and not make his piece exactly of the tints of an old original, but finish his colouring from truth and nature. This was the practice of all the great colourists: some of whom, however, resigned the operation of harmonising and heightening their tints to time alone, while others produced this effect with their own hands.

The principles of colouring, may, in general, be considered as included under the four following heads:—1. *Veracity.* 2. *Force.* 3. *Gradation* or *Keeping.* 4. *Harmony* or *Union.*

Veracity, or truth of colouring, is so obvious to every understanding, that nothing need be said to enforce an observance of its laws. The painter need not be told that objects must have their natural colours; that grass must be green, snow white, &c. Inattention to this rule scarcely deserves the name of false colouring, it is downright absurdity: but there are many instances where the young painter may depart from veracity, without himself perceiving his mistake. In many natural objects, of the same species, and of the same colour, we observe a quite different tint in different individuals; this obtains more universally in the vegetable kingdom than in any other part of nature: different sorts of the same fruit have different hues, even among those whose general colour is green: the different foliages of trees vary no less in their tints; and among the various greens of the humble and useful plants of a kitchen garden, we can scarcely discover two exactly of the same tint. Drapery is also greatly diversified, and its display demands a strict adherence to truth: the various qualities of the articles of which our clothing is formed, though of the same colour as nearly as the manufacturer can make them, strike the most vulgar eye, and that at a considerable

distance, with very different effects: a piece of cotton, a piece of broad-cloth, a piece of silk, and another of satin, may all be dyed with the same ingredients; but how different will be their hues! and, perhaps, the art of man could not render them perfectly alike in this particular. The different qualities also of the same cloth, as being finer or coarser, have a surprising effect in its tints. All these circumstances, and many more, which the student will meet with in his observation of natural and artificial objects, must deserve his utmost care and attention, or his work will be destitute of truth, which will destroy all its other beauties, however numerous.

Force is that artful combination and management of the subject, by which the figures are placed in such a manner as to produce the greates and the desired effect. The principal objects in a piece are to be brought forward, placed in a conspicuous situation, displayed to advantage by vigorous colours, and properly contrasted. Force owes much of its effect to a judicious management of light and shadow, termed by artists, *chiaro oscuro*, or light and dark; without which neither relief nor force can be given to any subject. The painter who has attained the happy method of introducing the most agreeable and just lights and shadows, forming masses of considerable extent and length, and not breaking the subject into trivial divisions and subdivisions, is said to have a just knowledge of the *chiaro oscuro*, or to produce a great effect. The *chiaro oscuro* is, therefore, the art of distributing the lights and shades of all objects whatever; not merely as they would fall in any natural objects, but they are to be placed in such a manner as to give the greatest life, force, and strength to the piece, when viewed altogether, and considered as a whole. It is only by a judicious opposition and heightening of lights and shades, by accurate and careful degradation of tints, glazings, reflexions, and smart touches of the pencil, that the painter can give that relief to his subjects, which will convey the ideas of roundness and projection; or produce the appearance of recession, interval, and distance.

To excel in the *chiaro oscuro* the painter should know both how to *collect* and *manage* his lights, and also to make them *support* each other. If a piece have ever so many lights and shades, and they be broken and subdivided into small parts, without being judiciously opposed to each other, they will no more relieve the objects they accompany than do the chequers of a draft-board; but if the relative parts are harmonised and assembled, shade to shade, and light to light, they form a powerful combination, on which the eye, as well as the mind, dwells with pleasure. A staring white relieved by an intense black, or a black accompanied with white, may produce a certain harsh force, and a species of effect, but can never impart that satisfaction to the observer, which arises from a view of harmonised lights and shades. This can be effected only by the introduction of gradatory tints, which fill up the intervals between the extremes, and temper and accommodate the lights and shadows to each other; whereby they are rendered more pleasing; and the disagreeable effect of sudden and violent contrast destroyed. In a word, collection, union, and combination, form the first principles of the *chiaro oscuro*. The *chiaro oscuro* also demands support. As every subject requires a different mode of treatment, any particular rules for the disposition of lights would be nugatory. It may, in general, be observed, that one light in particular should preside, and claim a superiority over all the others; but the lights should be separated and varied in their

shades: there should be at least three lights: the secondary lights should, for the sake of harmony and union, be nearly equal in brightness, though not in magnitude, with the principal: and though it be generally directed, that the principal light be placed in the middle of the piece, the student must beware of understanding the term in a strict mathematical sense; for if the centre of this light fall exactly in the centre of the piece it will produce a stiff and ungraceful effect. The strength of the principal light should fall *near* rather than *in* the middle of the picture: it should catch and be diversified chiefly round its principal union: and its brightness should be embellished by placing near it the attendant and circumjacent shadows. In order to judge whether or not a piece be well executed, with regard to the *chiaro oscuro*, it should be examined at such a distance that the subject cannot be distinguished, when it should form an agreeable mixture or correspondence of lights and shadows: on a nearer approach it should, by its force and powerful relief, attract the eye of the spectator, and fix his attention so as to induce him to investigate and examine its composition and management. If it have this effect, it may reasonably be concluded it possesses all, or most, of the requisites of the *chiaro oscuro*.

"The means," says Sir Joshua Reynolds, "by which the painter works, and on which the effect of his picture depends, are light and shade, warm and cold colours: that there is an art in the management and disposition of those means will be easily granted, and it is equally certain that this art is to be acquired by a careful examination of the works of those who have excelled in it. I shall here set down the result of the observations which I have made on the works of those artists who appear to have best understood the management of light and shade, and who may be considered as examples for imitation in this branch of the art. Titian, Paul Veronese, and Tintoret, were among the first painters who reduced to a system what was before practised without any fixed principle, and consequently neglected occasionally. From the Venetian painters Rubens extracted his scheme of composition, which was soon understood and adopted by his countrymen, and extended even to the minor painters of familiar life in the Dutch school. When I was at Venice the method I took to avail myself of their principles was:—When I observed an extraordinary effect of light and shade in any picture, I took a leaf of my pocket-book, and darkened every part of it in the same gradation of light and shade as the picture, leaving the white paper untouched, to represent the light, and this, without any attention to the subject, or to the drawing of the figures. A few trials of this kind will be sufficient to give the method of their conduct in the management of their lights. After a few trials I found the paper blotted nearly alike; their general practice appeared to be, to allow not above a quarter of the picture for the light, including in this portion both the principal and secondary lights: another quarter to be as dark as possible; and the remaining half kept in mezzotint, or half shadow. Rubens appears to have admitted rather more light than a quarter; and Rembrandt much less, scarce an eighth; by this conduct Rembrandt's light is extremely brilliant, but it costs too much; the rest of the picture is sacrificed to this one subject. That light will certainly appear the brightest which is surrounded with the greatest quantity of shade, supposing equal skill in the artist. By these means you may likewise remark the various forms and shapes of those lights, as well as the ob-

"jects on which they are flung, whether on a figure, or the sky, on a white napkin, on animals, or utensils, often introduced for this purpose only: it may be observed likewise, what portion is strongly relieved, and how much is united with its ground, for it is necessary that some part (though a small one is sufficient) should be sharp and cutting against its ground, whether it be light on a dark, or dark on a light ground, in order to give firmness and distinction to the work; if, on the other hand, it is relieved on every side, it will appear as if inlaid on its ground. Such a blotted paper, held at a distance from the eye, will strike the spectator as something excellent for the disposition of light and shadow, though he does not distinguish whether it is a history, a portrait, a landscape, dead game, or any thing else, for the same principles extend to every branch of the art." The highest finishing is labour in vain, unless at the same time there be preserved a breadth of light and shadow: it is a quality, therefore, that is more frequently recommended to students, and insisted upon, than any other whatever: and, perhaps, for this reason, because it is most apt to be neglected, the attention of the artist being so often entirely absorbed in the detail.

Gradation of colours, or keeping, as it is called by artists, is that principle which directs the strongest and most powerful colours to be placed where the principal effect should fall, and withheld from all accessory and inferior parts, which should, consequently, have weaker tints, and thereby be kept down and softened. This rule forms a part of aerial perspective; and is regulated by the same laws as are observed in the *chiaro oscuro*.

The next rule in colouring is to preserve *union*, and consequently produce *harmony*. This is effected only by a judicious selection, systematical arrangement, and scientific natural situation of colours; which, like the other branches of the art, are not to be attained but by an attentive observation of both nature and art, united with a persevering industry. The general principles of colouring are nearly the same in whatever subject the painter attempts. For example: if the effect of a piece be required to fall in the centre of the picture, (as is generally the case) this part must be the seat of the hero or principal object; here must also be the strongest light and shadows; the strongest colours; the greatest force; the greatest veracity; and, in a word, it is the seat of whatever tends to make the picture conspicuous. It may be considered as the focus of a lens, where all the rays unite with their greatest force; and from which, as they diverge towards the extremities of the picture, they gradually weaken, till they become lost, or nearly so, in the ground: the lights, colours, force, and every other effective principle, gradually declining, according to their distances from the centre, and their approximation to the boundaries of the picture. It is not, however, to be understood, that this declension of light, colours, &c. so uniformly prevails as to admit of no exception; on the contrary, the principal light should always be made to catch on some adjacent objects, on which it suddenly revives and shines, but yet in strict subordination to the light of the principal object: the same is to be observed of the principal colour, which, on many surrounding objects, often shines with a refulgence nearly equal to that of the principal subject of the picture. To produce effect in colouring, the learner must be acquainted with the nature of colours, with regard to sympathy and antipathy; warm or mellow and cold colours. By the judicious management of these, this branch of his art is brought to perfection. Sym-

pathetic colours are those allied in their tones, as brown and dark red; yellow, orange, flesh colour, &c. Sympathetic colours always produce union or harmony, but destroy variety. Antipathetic, or opposite colours, are those which are contrary in their tones, as blue and red; yellow and brown; these colours contribute to force and variety, but exclude union or harmony. Warm colours are all those which bear a certain modified resemblance to the effect of sunshine: which being of a bright glowing yellow, indicates all colours, nearly allied to it in tone, to be warm also; on the contrary, blue is accounted the coldest of all colours, and is, for that reason, the most difficult to introduce and manage successfully: consequently, green, and all other colours approaching to blue, are of a cold nature. Blue, however, though so difficult a colour to use with success, is very useful to the painter: as it produces, with others, more force, variety, and contrast, than any other tint. There are four principal modes of producing harmony of colours, each of which has its partizans, and its peculiar excellencies and defects. The first partakes of the Roman manner: the colours are laid on in a full and strong body, as may be seen in all the best works of that school: a very good specimen of this kind is Raphael's famous piece the *Transfiguration.* The second method of harmonising the colours may be called the Bolognian style; it is produced by what ancient painters called, *corruption of the colours;* that is, by mixing and breaking them, till there was a general union in the whole, and nothing left in the piece which could give the least idea of the original colours on the pallet from which those were formed. The next manner is called the Venetian, being first practised in that school: but it is seen to more perfection, and learnt with far greater advantage, in the works of Rubens. Here the brightest colours possible are admitted, as also the two extremes of warm and cold colours: these are reconciled by being dispersed over every part of the picture, till the whole appears at a distance, with regard to colour, like a bunch of flowers. It is evident that, if any preference be given to either of these methods, this decidedly claims it; as it is the manner adopted by that great colourist Titian. Simply considered, with regard to its colours, it produces a splendour of effect which eclipses whatever is brought into competition with it; and has always ranked highest in the estimation of all able critics. The last method is that adopted by Guido, and followed with great success by many artists of the Dutch school, particularly the younger Vandevelde, and the younger Teniers. This manner is distinguished by a silvery grey, or pearly tint, which is predominant over the whole piece. The pictures of this style are always valued by the critics in proportion as they possess this silvery tint The cleanness, neatness, and delicacy of this mode of colouring, perfectly correspond with the subjects of Guido, who generally chose, and more particularly succeeded, in those subjects which abounded with female figures, angels, and children: and to these pearly tints the exquisite beauty of his pieces is much indebted.

To produce force, solidity, and strength, some part of the picture should be as light, and some part as dark, as possible. These two extremes are then to be harmonised and reconciled to each other, by a proper introduction of gradatory tints and demi-tints. Rubens has left us two examples of this rule, in two pieces; one in the cabinet of the Duke of Rutland, and the other in the chapel of Rubens at Antwerp, which serves as his monument. In both pictures is a female figure, dressed

in black satin, with shadows as dark as pure black can make them, but opposed to the extreme of brightness. Both pieces are eminent for their force and brilliancy of effect, and furnish a striking illustration of this rule. Though colouring, considered, as it really is, a mechanical part of the art, may seem not to deserve so great a share of the painter's attention; yet, when we reflect what effects colours are able to produce on the minds of both the uninformed observer and the critic, the young painter will be convinced that its study is, in a manner, indispensable. When he reflects that they give the picture its general air at first view, and arrest the spectator's attention as he passes along the gallery, or escape his notice from their insipidity, he will no longer hesitate to bestow that study upon them requisite for the completion of his art. He must avoid all trifling or artful play of little lights; as also an introduction of a variety of superfluous tints: a quietness and simplicity must reign over the whole work, which can only be effected by a breadth of uniform and simple colour. It is true, grandeur of effect may be produced by two different and nearly opposite methods: one is, by reducing the colours to little more than *chiaro oscuro*, as was the practice of the Bolognian school; the other is, by making the colours very distinct and forcible, like those of Rome and Florence; but still the presiding principle, in both these modes, and the cause of their success, is simplicity. Nothing is more simple than monotony; and the distinct blue, red, and the other colours in the draperies of the Roman and Florentine schools, though destitute of that harmony produced by a variety of broken and transparent colours, yet possess that effect of grandeur required; and strike the mind more forcibly than if they were harmonized by a greater number of tints; as martial music rouses the nobler passions by the sudden and strongly marked transitions from one note to another, while the softer passions are called forth by the melody of notes more united in their sound.

The great effect we observe in the works of the Venetian painters is produced by a circumstance which has been overlooked by most of the painters of the Roman and Florentine schools, as well as by many other artists: namely, that of making the principal masses of light of a warm mellow colour, yellow, red, or a yellowish white; not permitting the blue, grey, or green colour to appear in these masses, but to use a very small proportion of them only, to set off and support the warm colours. If this practice be not followed, the best colours, even in the hands of a Titian or a Rubens, will never produce harmony or splendour.

We have several instances of artists, eminent for academical merit, who have failed through inattention to this precept. Carlo Maratti and Le Brun were both deficient in their management of their colours. This is the chief cause of that heaviness of effect in their works. In the *Tent of Darius* by Le Brun, the principal light in the picture falls on Statira, who is very judiciously dressed in a pale blue drapery; and though this coldness be heightened with gold, yet it by no means enlivens the piece, which still possesses a heavy air; and does not answer the expectation raised by viewing the work. Neither did Poussin study a harmony of colouring, and grandeur of effect; for he often made a spot of blue drapery to receive the light, when the general hue of the picture was inclinable to brown or yellow.

Many of the Dutch and Flemish painters used white for the principal

light of the picture; but it is more conformable to nature, and has a far better effect, to make the principal light of a warm colour, like white illuminated by the rays of the setting sun. This was the practice of Titian. The beauty of this manner never appears more striking, than when, in a collection of pictures, we see one of Titian's portraits hanging by the side of a Flemish picture, (even though it should be the production of Vandyke) which always becomes cold and grey in the comparison. This method is a just imitation of nature, where the illuminated parts of objects are of a warmer tint than those in the shade. It is, therefore, only presenting to the eye the same effect it has been accustomed to feel, and which, in that case, (as in every other) never fails of producing that beauty which gives pleasure to every beholder.

One precept, in particular, with regard to his lights, the painter must not overlook, and which has been before mentioned, under the other branches of the art; namely, that he do not copy nature too servilely. It is often necessary, that either his principal lights or shades should be lighter or darker than they appear in natural objects. Truth must sometimes be sacrificed to art, to produce force, harmony, and effect. An artist must ever hold a balance in his hand, to determine the value of different qualities, that when some error must be committed, he may chuse the least. A part must often be sacrificed for the good of the whole. Rubens has left us a remarkable instance of this conduct in a picture of a moon-light scene. He has not only diffused more light over the picture than prevails in nature, but has given it those warm and glowing colours, which distinguish all his other pieces. It is so unlike what other painters have given us of moon-light, that, were it not for the stars he has added, it might be easily mistaken for the light of a fainter setting sun. Had he made it more natural, he must have destroyed the harmony proceeding from contrast and variety of colours: and he judiciously supposed that the eye should be satisfied, above every other consideration. The moon also does not possess so great a superiority of light over the objects it illuminates as it does in nature. This is another mark of the pure taste of Rubens: had he preserved the same gradation of light between the moon and the objects, as obtains in nature, the picture must have consisted of one small spot of light only, and, at a little distance from the piece, nothing but this spot would have been seen. For the same reason, namely, to produce force and effect, the greater part of the colours of a picture must sometimes be kept down, in order to heighten others, by contrast, to a greater degree than colours could otherwise bear. This is the case in representing armour, and other shining substances; where we have no other pigment but pure white, to imitate the greatest light of shining objects: this would never preserve a due superiority over the flesh-colour, were this colour not kept down to a very low tint. But this effect of art (like all others) may be carried too far, as was done by Rembrandt, in a picture of Achilles, where, in order to preserve a due gradation, between the lustre of the armour and the face of the warrior, the colours of the whole picture are lowered to that degree, and the picture rendered so black, that it cannot be seen without a peculiar light, and even then with difficulty.

“ The art of colouring “ says a French writer on painting,” is much more difficult than is usually supposed: during three hundred years

since painting has been revived, hardly more than eight or ten masters have been excellent colourists. Perhaps also the infinite variety included in the necessary objects and models of study, precludes the establishment of rules and directions on this art.

"Shall we enquire if Titian had better eyes than others? or had he formed to himself superior rules? If by rules he attained his merit, may not those who tread in his steps derive great advantages from the study of his works, from attentive and judicious observations upon them? But for this effect is requisite an attentive disposition of mind, and an aptitude to penetrate the true causes of those effects we admire. How many painters have copied Titian many years, seemingly with their utmost abilities, who yet have never understood the skill and delicacy of the colouring in this great master! The painter, born for the art, flies with his own wings, and liberates himself from bad habits; but it must be acknowledged that a great master is no less rare than a great hero, his natural genius having to surmount all obstacles.

"The truth of colouring consists not in giving to objects precisely the true and exact colour they possess in nature; but to contrive so that they shall seem to have it; because artificial colours not possessing the strength and truth of those in nature, the painter's must be rendered equal, by comparison between themselves; whether by weakening some, or by strengthening others. The artist who wishes to imitate the colours of nature, should vary his colouring according to the subject, to the time of the day, the moment of the action, and scene of the picture; for the whole tone of the piece ought to agree with the action. If the subject be joyful, let the colouring be gay; but melancholy and sombre, if the subject be terrible, or afflictive. Although it may be admitted, generally, that a painter is master of his effects; and, like a musician, who plays a *solo*, may give what pitch he pleases to his instrument; yet it is equally true, that painters (especially landscape painters) ought to adhere to certain rules, independent of their caprice. The times of the day, morning, and evening; clear weather, or rainy; fog or sunshine; do not present the same tone of colours, in the same objects, but vary their brilliancy and splendour. The more serene is the weather, the clearer and brighter are the colours; rainy and hazy weather deprives them of their force. When evening approaches, all nature seems to feel very sensibly the absence of the sun, and, as if it regretted the separation, its colours become feeble and languid; they vanish with him, revive at his return, and augment as he approaches the zenith.

There is another auxiliary, from which the young painter may derive considerable aid in his knowledge of the *chiaro oscuro*, in his display of it to advantage, in faithfully representing the colours of his objects, and the actions of those in motion; namely the *camera obscura*, or darkened chamber. A very superficial knowledge of dioptrics will enable the student to discover the principles and effects of this simple but useful machine; of which a general notion is given in *Optics*, page 89.

Of Drapery. Many great artists, whose works have met with general approbation, have never condescended to distinguish the different kinds of drapery. With them the clothing is neither woollen, nor linen, nor silk, satin, nor velvet; it is clothing and nothing more. It is the inferior style of painting only that marks the variety of stuffs. The

art of disposing of the folds of drapery, so that they shall have an easy communication, and gracefully follow each other, with such natural negligence, as to look like the effect of chance, and at the same time shew the figure under them to the utmost advantage, requires the nicest judgment; and makes a very considerable part of the painter's study.

It was the opinion of Carlo Maratti, that the disposition of drapery was a more difficult part of the art than that of drawing a human figure; as the rules for delineating it could not be so well ascertained, as those for drawing a correct form: consequently a student, he said, might be more easily taught the latter than the former. It would be presumptuous to contradict so great an artist in his opinion of that particular branch of his practice in which he claimed his chief excellence. Yet it must be confessed, by his artificial management of the subject, (which is too apparent) he is inferior to Raphael even in this particular. Nevertheless, a judicious display of drapery is an excellence somewhat rare; and, perhaps, for this reason that, in common with many other parts of the art, it is not to be attained by a mechanical and slavish attention to rules, but by a correct taste and just knowledge of truth and nature.

As the just delineation of the folds in drapery depends on a successful display of the *chiaro oscuro*, the student must, by all means, render himself perfect in giving relief to his figures; for every fold, to make it appear natural, must be properly relieved with shade. Drapery is not so much intended to conceal the figure, as to discover the form of the members it covers: and as the inequalities of a surface are discoverable by the inequalities of the water that runs over it, so the posture and shape of the members must be discernable by the folds of the garment that covers them. This remark serves to shew us the absurdity of those painters who have loaded their figures with a great mass of drapery, abounding with a multitude of superfluous folds and needless windings, so that the whole appears a mere bundle of clothing, from under which the body has fled. It should also indicate though not too minutely, the quality and nature of the stuff of which it is formed. The great success of some artists in draping their figures was, in a great measure, the consequence of their practice, quite different from that at present followed. They first drew the naked figure, and clothed it afterwards: those who proceeded on a similiar principle, succeeded also equally well in displaying the several joints, members, and muscles of the human body: these first drew the skeletons of their figures, and afterwards added the muscles, and clothed them with flesh. It is not meant to recommend the revival of this practice to modern students, it would engross too much time; and is so unlike the present mode of painting, that the young artist must pursue the solitary path alone; and could, perhaps, meet with no assistance, or even advice, in the course of his progress, should he ever find himself involved in a difficulty. Nevertheless for the young artist who is not startled at obstacles, a few examples of this nature would not be time lost; provided he have acquired some facility in drawing, or at least in sketching outlines. The practice would, at least, give him more permanent ideas of the *rationale* of drapery and design, as well as of the expression of the muscles and joints of the human figure, than perhaps twice as much time spent in mere copying. But

one caution is absolutely necessary: those admired relics of antiquity, the Greek statues, are by no means proper models for the student's imitation in this part of his studies. It is certain the ancient sculptors clothed their statues with truth and grace, as appears from many of them still extant: but it must be remarked, that they seem always to have supposed their originals clothed with wet garments, and those of a very fine and delicate texture, which, consequently, clinging to the parts of the body, shewed, in a great measure, the natural shape of the members. A loose garment, abounding with folds, can never be justly represented in stone. The various windings and folds would appear mere rocks of stone; and, instead of imparting grace or beauty to the figures, would perfectly destroy both. In this respect, therefore, painting and sculpture are very different: in the former, the folds, however flowing or numerous, can always be pourtrayed, and the true form of the figure seen under them. Should the painter habituate himself to drape his figures from the ancient statues, he will contract a dry and hard style; and fall into an error which has been committed by some great masters, who, from accustoming themselves always to drape with very light stuffs, which sit close to the body, have afterwards treated the coarsest articles of drapery in the same manner, so as even to exhibit the muscles which lie underneath them.

The best and only models for acquiring just ideas of drapery, are nature herself, and, as preparatory thereto, the paintings of those modern masters, who have pourtrayed her with the greatest truth in this branch. The principal of these are Raphael, Paul Veronese, Andrea del Sarto, Rubens, Guido Reni, and Albert Durer. These artists excelled particularly in giving a graceful flow to their draperies, displaying the form of the wearers body, and distinguishing the particular kinds of clothing. The flow of their drapery is soft and gentle; the gatherings and plaits are so contrived, as not only not to hide the body, but to add to it grace and dignity. The quality of their clothing, whether linen, silk, woollen, or any other article, is as readily distinguished by the form and flow of the folds, the light and shade of the clothing, and its lustre, as the age and sex of the figures are known by their countenances.

It may appear superfluous to inform the student that the drapery should correspond to the age, character, and nation of the wearer. Common sense alone would convince him of the absurdity of attiring an ancient Grecian or Roman, in the habiliments of a modern English gentleman; or of omitting to furnish a magistrate with his robes; or of describing the natives of the South Sea islands with the redundant dresses of Europeans. These are the extremes of improbability: other deviations from truth are more easily committed, and less liable to detection. It is not recommended to the student to permit the costume of his drapery to occupy all his attention; it is sufficient if it come within the general laws of probability: for example, in pourtraying a senator of Rome, all that is requisite is, that he be draped in the robes of that order of men, as generally worn at the time when the republic was in its most flourishing state, without adverting, in this respect, to the precise age in which the senator lived, and consequently to the trifling variations which ever-changing fashion is continually imposing. The general play of the drapery, and form of the folds, should plainly indicate whether the figure be at rest or in action; and if in action, whether that action be beginning or ending; whether

slow, or quick, or violent: if we observe the flow of drapery in natural objects, we shall soon acquire just ideas of the matter. As we move in a resisting medium, namely the air, which ever way we move, the drapery will flow the other way, more or less, and that in proportion as our motion is quicker or slower; as the wind, more or less, counteracts our progress; and as our drapery is, more or less, light and flowing. In ascending an eminence the drapery is uniformly pressed downwards by the weight of the superior air; but, on the contrary, in descending, it is supported and extended by a similar resistance.

A penurious scantiness, and superfluous redundancy of drapery, are equally injurious to the great style. The figures of some great masters appear as if the artist, through mere poverty, had grudged them clothing; while others, as Albano said of Guido, perhaps too severely, are rather tailors than painters. The foregoing rules will be more clearly illustrated by the example of one of the greatest masters of drapery, who, undoubtedly, excelled all others in that ideal beauty to which this part of the art is so much indebted. Raphael imitated at first his master Perugino's manner of drapery; and he brought this manner to perfection by studying the works of Masaccio, and of Bartholomeo; but he departed entirely from the taste of the school in which he was educated, when he had seen the works of the ancients. It was the basso relievo of antiquity which pointed out to him the true flowing of drapery, and he was not backward to introduce it. He discovered, by attending to the principles of the ancients, that the *nudo* or naked is the principal part; that drapery is to be regarded altogether as an accessory, and that it is intended to cover, not to conceal; that it is employed from necessity, not caprice; that of consequence the clothes should not be so narrow as to constrain the members, nor so ample as to embarrass them; but that the artist should adapt them to the size and attitude of the figures intended to wear them. He understood that the great folds should be placed on the broad places of the body; and where the nature of the drapery required small folds, that it was necessary to give them a projection, which indicates a subordination to the principal parts.

Of Disposition. When the painter has chosen the subject of his intended work, his peculiar skill appears by the manner in which he narrates, if we may so speak, the circumstances of the story. The poet and the historian have, in some respects, great advantages over the painter, in being able to prepare the mind of their reader, by a gradual and natural display of such events and accidents as lead him to a full comprehension of the subject handled. The painter, on the other hand, is restricted to one particular action of his story, to absolute unity of time and place. It is therefore, incumbent on him to fix on that particular point of his subject which affords the most natural opportunity, not only of expressing his main scope itself, but of conveying to the spectator an idea of the circumstances which preceded and followed it. Invention must, therefore, be a most important point in the science of painting: and without an excellence in this part of the art, no man can ever rise to the reputation of a great painter. By invention it is not meant to express the discovery and representation, on canvas, of the truth of all circumstances as they actually took place in the scene presented to the eye, but only all such as are probable. By this probability may be introduced whatever is intimately connected with the subject, and likewise whatever, by its sublimity or beauty, may be most

capable of exciting the desired feelings in the mind of the spectator, and force him, in some degree, to forget that it is only a representation, and not the reality of the subject. As in imitating nature, we are by no means to take any individual object, as it really exists in nature around us, for our model; but to select, from the whole species of objects, all such particulars as possess the greatest excellence: so in the arrangement of a piece of painting, we are to choose and draw together whatever circumstances or allusions may seem to have the most powerful tendency to convey to the observer those sensations and ideas which we desire to excite. It is the business, nay, the duty, of the naturalist and historian, to represent objects and facts correctly and precisely as they exist or occur, with all their blemishes or imperfections: but the painter, who ought to be an ideal historian, resembles the poet, who does not copy but imitates the objects with which he is conversant: that is, he works by his imagination, and represents objects and events with all the perfection of which the species is susceptible. This proceeding is deeply rooted in our nature. By habit we come to associate certain ideas together, which have not always a necessary connection with each other. The painter must, therefore, be most careful to present no object nor feature to the spectator, which, by these associations, can recal to his mind sensations either contrary, or merely foreign to the great scope of his piece, at the same time that he introduces all such circumstances as are calculated to produce the effects he has in view. Here *La belle Nature,* as the French call it; nature methodised and made perfect must be his guide. Hence, circumstances of the subject exalted to the highest degree of beauty and sublimity of which they are susceptible, although they never really happened, are fully entitled to appear in the works of the painter of genius and taste. It is in this part of their several arts that the poet (or *maker,* as he was formerly very properly termed, and as the word signifies in the Greek) and the painter resemble each other: and they are both enabled to throw into their productions more of the spirit of philosophic instruction and entertainment than the historian. In the composition of their works the ancient poets and painters had many advantages over the moderns, from their mythological system, which warranted the introduction of supernatural beings, not only allegorically, but as real actors in the scenes described and represented: a practice which gave a wonderful animation to their productions, and a facility in conveying to the minds of their admirers the precise conception it was their wish to excite. So far were their gods from being immortal, and placed at an infinite distance from their worshippers; so far was their religion from recommending humility and self-denial; that, on the contrary, it appeared calculated merely to flatter the senses, to inflame the passions, and to poison the imagination. Besides, their deities were in a manner visible, and to be met with at every step. The sea was crowded with Tritons and Nereids, the rivers with Naiads, the the mountains with Dryads, and the woods and fields with Nymphs and Fauns. The most powerful empires, the most noble families, the most celebrated heroes, all derived their origin from one or other of their divinities: nay, the gods themselves took a visible interest, and frequently mingled in the concerns of men. By the use of this machinery the ancients had a command of the imagination, which no modern artists can hope to attain. There have not been wanting, however, many masters of invention even among the moderns. Michael Angelo, as did his

predecessors in the art, Phidias and Apelles, enriched his productions by hints and ideas collected from the greatest poets, and threw into his works an animation, an expression, a language, if we may so speak, which has never been equalled. Raphael, by a similar process, directed by his own exquisite judgment and taste, has exalted nature as it were above herself, by giving her an aspect more beautiful, more animating, more sublime, than she is really accustomed to wear. Dominichino and Annibal Carracci come very dear to Raphael, in many of their pieces, in point of invention; and Poussin, in some of his works, as for instance, in his pictures of *Esther before Ahasuerus*, and *the Death of Germanicus*, has shown himself to be very great in the same qualification. But however ingeniously a piece may be imagined, that is, with what skill soever the painter may have arranged in his imagination the attitudes and countenances of the characters in his piece; if these figures are not arranged and situated in the picture, in such a manner as to contribute in the highest degree to the unfolding of his design, and to the production of delight in the spectator, he has done but half his duty.

The *disposition* of the several parts of a picture ought to be such as to express, in the most lively and obvious way, what the invention of the artist has provided. The chief difficulty in disposition is to produce the most artful and ingenious arrangement, at the same time that art shall be utterly imperceptible, and that the whole shall seem to be merely the result of accident. A painter, therefore, must beware of imitating the dry formal manner practised by the earliest modern artists, on the revival of painting; for they generally arranged their figures like so many couples in a procession: neither must he follow the example of still more modern artists, particularly of the French school, who, unable to express in the genuine language of unsophisticated nature, the passions and feelings of their figures, have represented them in a state of the utmost disorder and fluttering agitation; as if they were brought together for no other purpose but to quarrel and fight. It was one of the admirable qualities of Raphael, that he not only was able to shake off the yoke of education and prejudice, early contracted, and in some measure consecrated by his respect for his old master, Pietro Perugino, but also possessed so much true taste and knowledge of human nature, as to stop at the due medium between formal frigidity and extravagant attitude and caricatural expression. The disposition of his figures seems always, to the observer of taste, to be precisely what it ought to be, and correctly suited to the subject of the painting.

As in a dramatic or epic poem, or in a romance, there must be some hero or heroine, who sustains the principal part in the conduct of the piece, and to whom all the other parts, however subordinate, bear a due relation; so in painting there must be one principal figure which must arrest the eye and observation of the spectator, and to whom all the other figures must appear to be more or less subservient.

This effect may be produced in a variety of ways; as by placing the figure in the front, or some other conspicuous part of the picture: by exhibiting it, in a manner, by itself; by making the chief body of light to fall upon it; by giving it the most splendid and brilliant drapery; or, indeed, by two, more, or all of these methods together. Painters should follow the example of the best dramatic writers, who have generally composed their fable of the smallest possible number of persons; for nothing is so injurious to picturesque effect in painting, nor to dramatic

consistency on the stage, as the presence of figures or persons not necessarily connected with the matter represented, and whose appearance there is not obviously and necessarily required. Besides that a crowded picture is apt to give equal trouble to the spectator as a crowded road to the traveller; both are embarrassed and perplexed, and their attention is distracted from the main object of their pursuit. Some subjects, however, from their nature require a greater number, nay, even a multitude of characters; but still, in these, the figures are to be assembled in groups or masses, in different gradations, all indicating their subordinate relation to one principal group or mass, which ought to occupy, in the composition, a place corresponding to that of the principal figure or personage in a piece where but few figures are introduced. In breaking a composition into groups, the object is, that the eye, in passing from one object to another, may, with the greatest ease, comprehend the whole, by having a distinct classification and conception of the component parts. These groups must be put together with such skill as to coalesce in clusters, and these clusters again to unite in one whole, that there may be no contrariety in the grand scope of the piece; and that even when seen from a distance, the observer may be able to discover the subject represented. Nothing contributes more to this distinction of groups than a due attention to the nature and effects of the several colours employed; so as not to bring together such as excite pain, by their marked opposition one to another, or distract our attention by an affected diversity. When *chiaro oscuro* is judiciously introduced, it is of great service, in distributing the groups and masses of a large painting into their proper situations; and by the strong falls of shade, gives a grand effect to the whole composition. This method has been very successfully followed by Rembrandt, in a picture of the Virgin at the foot of the cross; in which the light darts in full splendour on her, through a break in the clouds, while all the other figures are more or less in the shade. Tintoret also was highly valued for his skill in enlivening his figures, by the effects of strong light and shade: and Polydore da Carvaggio was famous for his management of the *chiaro oscuro* in his bas-reliefs.

By means of the expression of the different degrees of light and colour of bodies, arising from their own shape, and their position with respect to other bodies and to the eye, and by what is called *aerial perspective,* or the art of giving a due diminution or gradation to the strength of light, shade, and colour of objects, according to their different distances, the quantity of light falling upon them, and the medium through which they are seen: and by carefully studying nature, and the works of her best imitators, the artist will be enabled, not only to separate his groups, but to make them appear at different distances, so as to leave proper intervals and passages between them.

On the subject of disposition, it may be in general remarked, that *action* is the principal requisite in a subject for history painting; and that there are many subjects, which, though very interesting to the reader, would make no figure in representation. Such are those subjects which consist in a long series of action, the parts of which have very close dependency each on the other; or where any remarkable point or turn of verbal expression makes a part of the excellence of the story; or again, where it has its effect from allusion to circumstances not actually present. An instance of this kind of subject is given by Sir Joshua

Reynolds, as having been recommended to a painter by a very distinguished person, but who, as it appears, was but little conversant with painting. It was what is related, in Dalrymple's Memoirs of Great Britain, to have passed between James II. and the old Earl of Bedford, in the council held just before the revolution. This is, doubtless, a very striking piece of history; but so far from being a proper subject for a picture, that it possesses not one necessary qualification. It marks no general or intelligible action or passion: it has a retrospect to other circumstances in history of a very complicated nature: and it is necessarily deficient in that variety of heads, forms, ages, sexes, draperies, &c. which sometimes, by good management, supply, by picturesque effect, the want of real interest in a history. The invention of a painter consists, not in inventing the subject, but in a capacity for forming the subject in his imagination, in a way best suited to his art, although it be wholly borrowed from poets, historians, or popular tradition. For this purpose he has full as much, perhaps more, to do than if the story itself were invented: for he is bound to follow the ideas he has received, and to translate them, as it were, into the language of another art. In this translation lies the painter's invention. He must, in a manner, new-cast the whole, and model it in his own imagination. Having received an idea of the pathetic and grand, in expression, he is next to consider how to make it correspond with what is touching and awful to the eye. This is a business by itself; and here begins the proper invention of the painter, which includes not only the composition, or putting the whole together, and the disposition of each individual part, but also the management of the back-ground, the effect of light and shade, and the attitude of every figure or animal introduced, or making a part of the whole. Composition is, therefore, the chief part of the painter's invention, and by far the greatest difficulty he has to encounter. Every man who can paint at all, can execute individual parts: but to keep those parts in due subordination, as relative to the whole, requires a comprehensive view of the art, that more strongly implies the possession of genius than, perhaps, any other quality whatever.

Of Illusion and Deception. It is a maxim universally received among painters, and held up for the guidance of young artists, that they are to imitate nature, and that objects are to be represented so naturally as to seem real. If we enquire to what extent painting may carry this illusion, it will be found that it deceives the eye so much, that the spectator is sometimes obliged to apply his hand, as in moulding, and bas-relief, in order to come at the truth. This deception may be properly employed in representations of fruits, flowers, and other parts of what is called *still life;* when so placed, that they can only be seen from particular points of view, and at certain distances. But no picture, containing a number of figures, and properly situated, was ever mistaken for real life. It is true that the portrait of a person, done by Coypel, and placed in a certain direction behind a table, is said to have so completely deceived a number of people, that they saluted it, taking it to be the person whom it represented; but, independently of the skill in the execution of the piece, it is clear that the chief part of the illusion arose from the circumstances of surprise and inattention in the spectators; effects which might, in such a case, have been produced by very inferior artists. This species of illusion, however, would be vain, and ought never to be attempted in compositions consisting of many figures,

supposed to be situated at different, and even considerable distances, from each other. There are many obstacles opposed to the perfection of this branch of painting, of which some, and those the most powerful, arise from our manner of thinking and judging on other occasions. These, together with the perception we have of the effects of light, on surfaces and colours of various sorts, never fail to convince us, that the scenes before us are merely representations, and not realities. Distance, figure, and magnitude, are not originally objects of our knowledge by the sight: for we only judge of these qualities of objects by experience and associations early formed in the mind; and are satisfied with the skill of the painter, when he lays his colours on the plain surface of the canvas, in such a manner, that the rays of light are reflected from it, as they would be, from the varied surface of the body imitated, to a spectator placed in a proper situation. Illusion in painting must always be imperfect, from the impossibility of rendering with truth, the shades which distinguish the most distant parts of the picture. These can only be imitated by obscure colours, on a plain surface, and all susceptible of reflecting light, according to their real distance from the eye: but our eye gives us the true plane of this surface, in opposition to the idea of distance which the artist wishes to excite: and this opposition naturally destroys the illusion; the defect of which must depend on the imperfection of the shades. This defect can never be wholly removed, but it may be in some measure remedied, although no painter even yet succeeded in giving a perfect representation of a shadow. What we call in nature a shadow, is no real being, but merely the privation of light, which, more or less, destroys colours, as it is more or less complete. The painter, however, has no way to represent this want of light but by employing colours, which, however dark and absorbent, do always reflect the light in a certain degree. To carry the imitation of shadow to the highest degree of perfection, it would be necessary to employ colours capable of darkening all others, as occasion should require; at the same time, that these colours themselves should furnish no marks of their own existence, by reflecting the different lights falling on the picture. This kind of negative colour, as it might be called, would perhaps be useful in practice; but such a colour is unattainable, because there is no body or colour in nature, which, in this situation, would not reflect one or other of the rays of light that fell on it. The want of illusion, therefore, must be owing to the imperfection of shading: and consequently cannot exist completely in painting. There is, however, another species of illusion, improperly so called, which is one of the chief parts of the art. This consists in giving to the whole piece, and to each individual part, by means of correctness of forms, and combinations of colours, and their general effects, such a resemblance to the truth, that the representation shall excite in the observer all the pleasure to be derived from an inspection of the original. In this consists the genuine truth of imitation, and this may be executed by pictures, on a small scale, as well as in those of a size equal to that of the objects represented, and containing any number of figures, at any probable distance, the one from the other. It may still, however, be questioned, whether this near imitation of reality be the greatest perfection of which painting is susceptible. It is admitted, that the greatest perfection is that which not only delights, at the first general view, but which will bear the test of the nearest and most critical examination. If, how-

ever, illusion, such as it has been described, were the chief merit of painting, then it would follow, that a person little versed in the art would derive as much pleasure from its productions as he who had the greatest skill. The greatest masters seem evidently to have placed but little reliance on this species of illusion, for producing the desired effects on the spectator. Even the works of Raphael are not, in this respect, superior to those of an ordinary hand: but, the grandeur of his ideas in composition, the choice of his forms, the beauty of his heads, not resembling any known truth; his ingenious and noble manner in drapery, not imitated from any known stuff, nor the dress of any nation; in short, all these, and other excellencies, are far superior to the simple imitation of the truth of nature, and fully warrant us to say, that illusion is by no means the source of the greatest delight in the productions of art. Those who have excelled in colouring, have approached nearer to perfection, in illusion, than others who have failed in that part of painting: and, perhaps, to this circumstance do they owe a great share of the admiration bestowed on their works. It is true, that the exquisite shades and freshness of colouring, remarked in the productions of Corregio and Titian, exceeding the ordinary beauties of nature, and only to be found in her most perfect examples, may not be considered as destroying illusion: but, on the other hand, it is certain that feeble, and less exquisite tints and shades, would carry the illusion to a higher pitch. Besides, that broad, easy, excellent manner of painting, that harmony of parts and of colouring, of which they have given such examples, proceeded from qualities far more exquisite than those which would have been requisite for the simple imitation of nature. All this seems to show, that the nearest resemblance to the truth of individual nature is not the sole object of painting; but that the art acquires a superior elevation, by superadding beauty and elegance to the most correct representation of objects; and it is in this acquirement that the first merit of the greatest masters is to be attributed. In examining the leading excellencies of painting, we observe that many of the most essential are of a very different nature from those whose great object is deception. For instance, in a picture, we admire the extent of genius, the gracefulness and propriety of attitudes, the formation and arrangement of groups, so that the best general effects may be produced, either by means of light and shade, or in the correct suitableness of each component part, to the situation and intention of the whole: the beauties of composition, therefore, are of a nature very different from those which go to produce illusion. Sir Joshua Reynolds has well drawn the line of distinction between the *illusive* and the *beautiful* in painting, in his third Academical Discourse, in which he has the following passages:—"The principle laid down, that the perfection of the painter's art does not consist in mere imitation, is far from being new or singular. It is indeed supported by the general opinion of the enlightened part of mankind. The poets, orators, and rhetoricians of antiquity, are continually enforcing this position; that all the arts receive their perfection from ideal beauty, superior to what is to be formed in individual nature. They are ever referring to the practice of the painters and sculptors of their times, particularly of Phidias, the favourite artist of antiquity, to illustrate their assertions. As if they could not sufficiently express their admiration of his genius, by what they knew, they have recourse to poetical enthusiasm; they call it inspiration; a gift from heaven. The artist is sup-

posed to have ascended the celestial regions, to furnish his mind with this perfect idea of beauty. "He (says Proclus) who takes for his model such forms as nature produces, and confines himself to an exact imitation of them, will never attain to what is perfectly beautiful. For the works of nature are full of disproportion, and fall very short of the true standard of beauty. So that Phidias, when he formed his *Jupiter*, did not copy any object ever presented to his sight; but contemplated only that image, which he had conceived in his mind, from Homer's description." Cicero, speaking of the same Phidias, says,—"Neither did this artist, when he carved the image of *Jupiter* or *Minerva*, set before him any one human figure, as a pattern which he was to copy: but having a more perfect idea of beauty fixed in his mind, this he steadily contemplated; and to the imitation of this all his skill and labour were directed."

The portrait painter, whose chief merit seems to consist in a minute correct representation of the individual he is employed to paint, ought, in the same manner, to give a nobler turn to his work, by introducing a fancy, a variety, and a dignity, borrowed from the higher branches of the art; and portraits ought to remind the spectator of the invention of history, and of the amenity of landscape. In painting portraits the artist ought not to appear to be raised upon the platform, but to have descended to it from a higher sphere. Portrait painters, when they attempt history, are very apt to be led by the habit of a close illusive imitation of persons, to run too much into minute detail. Their historical heads and figures too frequently resemble particular portraits; as was once the custom amongst old artists, on the revival of painting, and before generalization of figures and objects was either understood or practised. A history painter is to represent men in general; a portrait painter some particular man, and consequently a defective model. A great style in painting is sure to suffer, more or less, by any meaner mixture: but it often happens that the inferior may be improved by borrowing from the superior. Thus, if a portrait painter is desirous to raise and improve his subject, he has no other means than by approaching it to a general idea. He must leave out all the minute peculiarities of the countenance, and instead of a modern temporary dress, suited to the fashion of the day, bestow on the figure one more permanent, and to which no idea of meanness has been connected in the minds of his spectators. On the other hand, if a correct resemblance of the person be considered as the only object of his pursuit, the painter runs the risk of losing more than he can gain, by introducing general ideas drawn from the great body of nature around him. Hence it is so difficult to give an air of superior dignity or elegance to a countenance, without departing materially from the exact likeness generally required by those who sit to the painter.

Of Costume. *Costume* is an Italian term adopted among artists, to express the conformity of the representation of any fact to the fact itself, as handed down to us, or as it may be, on good reason and authority, supposed to have really happened. This conformity must be very comprehensive, including whatever relates to the manners of the times, to the characters or the persons concerned; to their dress and arms, to the customs of the place, the buildings, and style of architecture; to the animals, to the taste of the people, their wealth, occupations, amusements, &c. in fine, to whatever circumstances are peculiar to and characteristic of the fact to be represented. This enumeration

of particulars shews that the study of the costume is no slight undertaking. The artist must carefully consult the historic relations and original movements of the period on which he is employed; observing at the same time not to shock the eye of the spectator, by displaying such circumstances as would be in too violent opposition to the corresponding incidents and practices of his own day. He must speak, as it were, nothing but the truth; at the same time that he is not expected to unfold the whole truth. Again, it often nappens, that a piece composed of picturesque figures, derives considerable advantage from certain liberties used by the painter, calculated both to facilitate his own labour, and to gratify the spectator: for the professed judges of the performance are not habitually occupied with all the details of ancient or even modern history; or profoundly versed in all the circumstances by which a considerable departure from the correctness of costume is rendered conspicuous: nor are they so ignorant as not to perceive, or so careless as not to pay regard to those circumstances, without a due attention to which this branch of the art would become altogether arbitrary. Between these extremes the painter must guide his course, neither on the one hand sternly rejecting appropriate and admissible beauties, nor, on the other sacrificing all regard to probability. When no authentic historical details are to be procured, the artist is more at liberty to give scope to his invention: but he must be cautious how he introduces such objects as are familiar to the spectator; because all illusion would then be destroyed, and the piece would have more the air of a modern theatrical representation of the subject than of a historical narration. It has been much debated, whether the costume ought to be strictly adhered to in portrait painting. One party have alleged, that however much a particular mode (of dress, for example) may be authorised by the existing fashion of the times, yet, that it never fails, in the course of a few years, to become ridiculous, even in the eyes of those who at the time most admired it; and will, in all probability, appear still more extravagant and senseless to posterity. Their antagonists, on the other hand, have stated, that this correct fidelity, in point of dress, contributes powerfully to produce the genuine resemblance in the portrait; that it thus becomes a historical monument for the information of future times; that there is no fixed or universal and permanent costume, excepting in certain dresses of office and ceremony; and that those who are in situations requiring such dresses, ought naturally to be so represented. With respect to the propriety, or *becomingness*, of one mode of dress, taken as a part of the general idea comprehended under costume, it can only be said, that it has its due medium point, which nothing but good sense and taste can discover and ascertain. Neither can we reasonably determine to which of the different customs of various ages and countries we ought to give a preference, since they seem to be all nearly equally agreeable to or removed from nature. The European, when he has cut off his beard, and put false hair on his head, or bound up his own natural hair in regular hard knots, as unlike nature as he can possibly make; and often having rendered these immoveable, by the help of the fat of hogs, and covered the whole with flour, laid on by a machine with the utmost regularity; when thus attired, he sallies forth and meets a Cherokee Indian, who has bestowed as much time at his toilet, and laid on, with equal care and attention, his yellow and red ochre, on particular parts of his forehead or cheeks, as he judges to be the most be-

coming: whoever of these two persons despises the other for his attention to the fashion of his country; whoever first feels himself inclined to laugh, he is the barbarian. As Greece and Rome are the sources from whence have been derived all kinds of excellence, to that veneration to which these sources are entitled, for the knowledge and pleasure they afford us, we readily add our approbation of every practice and every ornament which belonged to them, even to the fashion of their dress. For it is a common observation, that not satisfied with these practices and ornaments in their own proper place, we make no difficulty of dressing modern heroes or senators in the fashion of the Roman armour or peaceful robe. Nay, we carry this so far as scarcely to endure a statue in any other drapery. Witness the grotesque ridiculous figure of a former Duke of Cumberland, with cocked hat and jack-boots, in Cavendish square, and the simple modest statue of Charles James Fox, just erected in Bloomsbury square. The figures of the great men of antiquity have come down to us only in sculpture: and in this branch we possess almost all the specimens of ancient art. We have so far associated personal dignity to those who are thus represented; and the truth of art to their manner of representation, that it is not in our power any longer to separate them. The case, however, is different in painting, because no excellent portraits having reached us from antiquity, similar associations have not been formed in our minds. Hence it comes, that we could no more bear the painting of a modern general, in the Roman military habit, than a statue clothed in the present regimental uniform. But since we have no ancient portraits, still, to shew how ready we are to follow prejudices of the same kind, we resort to the best authority among modern artists for a similar purpose. The great variety of admirable portraits with which Vandyck has enriched this nation, are not only valued for their real excellence as paintings, but our approbation is extended to the dresses of his figures, although their only merit is, that they were fashionable in the artist's own time. "He," says Sir Joshua Reynolds, "who, in his practice of portrait painting, wishes to dignify his subject, which we will suppose to be a lady, will not paint her in the modern dress, the familiarity of which alone is sufficient to destroy all dignity. He takes care that his work shall correspond to those ideas and that imagination which he knows will regulate the judgment of others; and therefore dresses his figure something with the general air of the *antique*, for the sake of dignity; and preserves something of the modern, for the sake of likeness. By this conduct his works correspond with those prejudices which we have in favour of what we continually see; and the relish of the antique simplicity corresponds with what we may call the more learned and scientific prejudice." In studying the costume in the works of even the best masters, the student is apt to be misled; for errors and inaccuracies, in this part of his art, abound in the productions of the most celebrated painters, both ancient and modern. The following examples will be sufficient to put him on his guard against implicitly copying, or admiring, whatever comes recommended to him, as the genuine works of artists, of the most deserved reputation. When Raphael, in his *Cartoons*, introduces Monks and Swiss guards: when he puts into a boat more figures that it is evident the boat could actually contain: when in the chastisement of Heliodorus, who attempted to destroy the temple of Jerusalem, Pope Julius the Second is represented as being

present: when in the donation of Constantine, in the Vatican, a naked boy is placed conspicuous in the fore-ground, astride upon a dog, in the immediate presence of the Pope and the Emperor: when Venetian senators are introduced while Pope Alexander excommunicates Barbarossa: when Aristotle, Plato, Dante, and Petrarch are brought together in the painting called the School of Athens, to omit the lesser improprieties of shoeless apostles, &c. every person must confess, that these, and similar offences against the truth of the costume, if they do not proceed from ignorance, or a defect of understanding in the artist, are instances of inexcusable carelessness. It is true, that many of these incongruities are supposed to have been introduced at the desire, or to gratify the humour of those for whom the paintings were executed: but other instances of offence against costume are not wanting, not to be so easily defended. Thus, when the dreams of Joseph and of his fellow prisoner in Egypt, are figured in circles in the air over their heads; when similar contrivances have been resorted to, by Albano, Parmeggiano, and others, is it not evident that no possibility can make these fictions have an air of truth; and that real and feigned existences are unnaturally introduced in one historical painting? As the errors of the most eminent men are always the most dangerous, particularly to beginners, the following strictures on much-admired productions of the late excellent President of the Royal Academy, by the pen of a very ingenious writer, cannot fail to be of service to the young artist:—" Mrs. Siddons is represented by Sir Joshua in the character (it is said) of the Tragic Muse: she is placed in an old fashioned arm-chair: this arm-chair is supported by clouds, suspended in the air. On each side of her head is a figure, not unapt to suggest the idea of the attendant imps of an enchantress. Of these figures one is supposed to represent Comedy, and the other Tragedy. Mrs. Siddons herself is decently attired in the fashionable habiliments of twenty or thirty years ago. If this be a picture of the Tragic Muse, she ought not to appear in a modern dress, nor ought she to be seated in an old arm-chair. If it be a portraiture of Mrs. Siddons she has no business in the clouds, nor has she any thing to do with aerial attendants. If this be Mrs. Siddons in the character of the Tragic Muse, the first set of objections will apply; for she is placed in a situation where Mrs. Siddons could never be." " Again, in the picture of the death of Dido, her sister is introduced, lamenting over the corpse of the unfortunate queen. This is possible; but the artist has also introduced *Atropos* cutting Dido's hair with her scissars; a being equally real and apparent in the painting with Dido or her sister. This appears to be an offence against mythological probability: but it is not the only offence against the truth of costume, with which the picture may be charged."

There is still one other breach of the costume, however common among painters, more offensive and inexcusable than any thing hitherto noticed; that is, the perpetual and unnecessary display of the naked figure. This is not the place to enquire whether more skill be displayed in painting the human body clothed or unclothed: but if the persons introduced in any picture are exhibited more naked than can be justified, by the probability of the times, persons, places, or other circumstances, this manner of treating the subject is a breach of the costume, proportionate to the deviation. This fault, however, is so common, and authorised by the example of so many of the most eminent artists, that it

is hardly noticed, when compared with the more violent offences against science itself, as well as against morality, which have been the opprobrium of the art of painting, in every stage of its progress. The same gross offence against propriety and decorum is too common in pieces of modern statuary, as may be seen in certain monuments lately erected, at the public expence, even in our churches.

Landscape Painting.

Landscape painting comprehends all objects presented to our view, in a prospect of the country; and is commonly divided into the *heroic* or *historical*, and the *rural* or *pastoral* styles: all others partake more or less of these. By the *heroic* style is understood those scenes which exhibit whatever is great, sublime, or extraordinary in nature or in art. The situations must be on a grand scale; the buildings introduced should be temples, pyramids, funeral monuments, altars consecrated to fabulous divinities, palaces or pleasure-houses of regular and splendid architecture, &c. so that, if nature is represented not as we actually see her every day, she at least appears as we think she ought to be. This style is an agreeable species of illusion, a sort of enchantment, when handled by an artist of genius and understanding. The danger of treating landscapes of this sort is that, where true genius and understanding are not possessed in a high degree, the artist is liable to fall into unnatural bombast, while he imagines he is arriving at the sublime. In this branch N. Poussin has been particularly successful. The *rural* style, on the other hand, represents countries, rather as they appear from the hand of nature than when improved by men. There she is seen simple, without ornament, and without artifice; being, as Milton says; *when unadorned adorned the most.* In this style the varieties of situation are infinite: sometimes extensive and open, at others confined and embarrassed. In one scene the shepherd appears with his flock; in another the solitary hermit, or the prowling beast of prey. Few painters have appeared in the world possessed of sufficient talents to embrace many of the chief branches of painting. In general the mind is so occupied by its attention to some particular parts of the art, that others, of perhaps equal importance, are neglected; and it generally happens, that those whose genius leads them to attempt the heroic style, think they have done enough when they present to the eye such dignified objects as have a tendency to raise the imagination; but disregard the inferior parts, as colouring, for instance, as beneath their notice. Those again who devote themselves to the *pastoral* style, give particular attention to colouring; as the part by which the greatest effects may be produced, in the way they chiefly aim at. Perhaps it would be better to combine these two styles, more frequently than is generally done; a practice of which they are both very susceptible, and which could not fail to render a work more interesting and pleasing to the greatest number of spectators.

A landscape comprehends a vast variety of parts, such as situations or openings, accidents of weather, air, clouds, offskips and mountains, verdure, rocks, fields, terraces, buildings, water, fore-grounds, plants, trees, figures, &c.

Situations or openings, mean the view or prospect of a country, and

require great skill in putting together, so that although only a portion of them be seen, yet the imagination is left abundant scope to extend the scene in all directions, without restraint, according to the specimen furnished by the painter; whether it be open or close, mountainous or level, cultivated and inhabited, or wild and desart. If the artist, however, has chosen to represent a flat regular country, he must, by the distribution of his objects, and a judicious arrangement of his shadows, give to the view that variety and interesting appearance which nature had refused it. Extraordinary situations never fail to please, even when the colouring has been but indifferently executed, so as to appear unfinished: but common objects or scenes, demand all the magic of a Claude to render them interesting. In whatever manner, however, this part be performed, nothing contributes to heighten the effect so much as the introduction of some accident, ingeniously contrived, and suited with probability to the scene.

Accidents, in painting, are various; such as withdrawing the sun's beams by the interposition of a cloud, so that some parts of the prospect shall be enlightened, while others are obscured. And although it be impossible to represent motion, in painting, yet admirable hints may be obtained from observing the strong effects of dense clouds passing over the face of a country, and producing the most characteristic lights and shades. As these effects depend on the shapes of the clouds, combined with their motions, unequal and irregular, the representations of them in painting are arbitrary, and furnish a wide field for the display of the artist's powers: at the same time, that Claude Lorraine, and some other great landscape painters, seem to have made no use of such natural incidents; because their effects counteracted that calm serenity which they loved to represent.

The Sky and Clouds. In the language of the painter, the sky means the ethereal firmament above us, or rather the air in which we breathe, and where clouds and storms are produced. This sky is of a blue colour, drawing more to a white, as it approaches the earth, on account of the intervention of vapours hovering along the surface of the ground, which being penetrated by the light, communicate it to objects, in a greater or less degree, according to their distance from the eye. It is to be observed, however, that this light being yellowish or reddish at sun-set, those objects partake not only of the light, but of the yellow or red colour; consequently the yellow light mingling with the blue sky, gives it a tint more or less greenish, as the yellow colour is more or less deep. This observation is universal and infallible: but there are many others which the painter must make on the ground, marking them with his pencil as they occasionally appear: for there are, in the various appearances of the sky and light, a multitude of curious circumstances, which can neither be described nor readily accounted for. Thus we often observe, in the brightest part of certain clouds, a fine red colour, at the same time that the light which illuminates them is of a lively yellow. Various reds are likewise visible in different clouds, whilst those red parts are all illuminated in one place. Such colours and appearances seem to be produced by other natural causes than those to which we owe the beautiful arches of the rain-bow. These effects are most observable in an evening, when the state of the weather approaches to a change: before or after a storm; or when it is not entirely over, but leaves some marks of its existence, sufficient to attract our notice. The

property of clouds is to be thin, and of an airy texture; their shapes, though of endless variety, ought to be carefully observed and studied from nature, as they present themselves to the eye. In order to make them look thin, in a picture, the grounds over which they pass ought to be made to unite with them, as if the clouds were transparent, especially towards their edges: But if the clouds are to be represented of considerable thickness, then the reflections from them must be so managed, that without entirely destroying their transparency, they may be made to unite with other clouds in their neighbourhood. Small clouds, in a painting, seldom have a good effect, and betray a feebleness of manner in the artist, excepting when they are so near one to another, as, in a general way, to be considered as forming only one object. Upon the whole, it must be remembered, that the character of the sky is to be luminous, and that consequently all objects on the earth must be inferior in brightness. The only objects which can at all rival the sky, are water and polished surfaces, susceptible of luminous reflection. The artist must also recollect, that although the sky be luminous, it is not always equally bright in all places, nor to be so represented. On the contrary, he must distribute his lights in such a manner, that its greatest force may fall upon one place of the piece; and also to make this bright place still more distinguished, or to give it more relief and effect, by contrasting it with some object on the ground, such as a tree, a tower, or other elevated body, of an obscure colour. This principal light might be also heightened, by an arrangement of clouds possessing a borrowed light, or inclosing it between them, whilst their own obscurity is gradually communicated to all the surrounding objects. Of this artifice we have many examples in the performances of the Flemish school.

Offskips and mountains. The *offskip,* or what the French call *lointain,* is closely connected with the appearance of the sky, by which its strength or faintness is determined. That is to say, the offskips are darkest when the sky is most charged with clouds, and most enlightened when it is brightest. The shapes and lights of the sky are often intermixed with those of the mountains, by the appearance of clouds passing between their ranges, at a great distance; thereby affording room for the artist to produce very picturesque effects; particularly when these mountains are so elevated as to have their summits and slopes covered with snow, interspersed with masses of bare rock, in suitable situations: for it is to be recollected, that it is not entirely owing to the absolute height of a mountain, that the snow remains upon it; but principally to the nature of the surface. Thus, for instance, the noted mountain, *Mont Blanc,* at the angle of the Alps, on the south side of the lake of Geneva, so called from its constant white covering of snow, is terminated by a convex surface of some extent, sufficiently level to retain the snow; while some other pinnacles of rock, shooting up from its sides, but to an elevation considerably less than itself, are so steep, that the rains and snows have no footing on them. In managing offskips the painter must shew his skill in combining them properly with the nature and character of the country represented, as well as with the general scope of the picture. They are commonly of a blue cast, from the intervention of the horizontal stratum of air through which they are seen: but this blue cast gradually diminishes or increases, as the objects are nearer or more remote from the eye, and these appear more or less

in their own natural hues. In representing the distances of mountains, care must be taken to round them off by proper gradations of tints, so that those which are intended to appear at the greatest distances from one another may be given with the greatest difference of colours. Their contours must be so delicately defined as not to appear like different pieces of scenery, or painting, placed one behind another, and so attached to the canvas. The air at the bottom of a mountain being, as was already observed, more loaded with vapours than that at the top, is consequently more capable of reflecting rays of light. If the principal light, therefore, be placed in a high situation, the whole mountains will be equally illuminated, or only partially darkened by the interposition of a cloud: but if the source of the light be placed low, or near the horizon, then the tops of the mountains only will be strongly enlightened, as well as other objects receiving the light in a similar direction. Although objects are diminished in size, and appear with fainter colours, as they retire from the front of the picture; yet this appearance, correctly copied from nature, does by no means prevent the artist from availing himself of the use of *accidents* of the atmosphere, by which strong lights and shades may be introduced in particular situations, to give a picturesque effect: but in this, as in all other parts of the work, judgment, founded on a careful observation of the phenomena of nature, must guide his pencil.

Of verdure or turfing: that is the green colour of the surface of the ground, produced by the herbs and plants covering it. This admits of great diversity, according to the nature of these plants, and the season of the year, which occasions great changes in their appearance. This variety supplies the painter with an opportunity of adorning his work with an infinite variegation of tints, all tending to give a strong air of truth to his imitations.

Of Rocks. The varieties of rocks, in respect to colour, form, and composition, are infinite; but still, in all these varieties, there are certain characteristic features, by which a rock is distinguished in its natural state, and which can only be known by sedulous observation of the real objects. Some present themselves in easy sloping banks, surrounded with shrubs, others in huge blocks project, or threaten to fall down a precipice. At one time they appear in one vast mass, or lie scattered in detached fragments. But whatever be the diversity of their shapes, the crevices in their surface, the breaks and hollows running inwards, the shrubs, the moss, the stains produced by time, their sudden changes and irregularity of outline, their roughness of exterior appearance render them peculiarly picturesque: the painter all the while taking care in representing them, not to overstep the modesty of nature, by assigning to his rocks, situations, forms, or colours, such as are not generally observed. A rock by itself has a tendency to inspire melancholy, from the idea of solitariness: but when ornamented with herbs, shrubs, or overhanging trees, it breathes a more animating air. When accompanied by water, falling or gushing from their sides, or even peacefully bathing their feet, rocks become a source of the highest delight to all lovers of unsophisticated nature.

Of grounds or land. By these terms painters mean distinct portions of land, partly of an uneven surface, interspered with trees; but not so much so as to be considered as either a hill or a wood. Such portions of ground as these are of infinite service in representing the gradations

of distance in a painting; because they glide into one another with a natural union, in shape, in colour, and in light and shade. These *grounds* ought not to be divided into many portions, detached from and unconnected with one another; lest forming, as it were, different particular scenes or points of view, they distract the attention of the spectator, and thereby destroy the unity of the whole landscape. Great skill and judgment are nevertheless necessary in representing such objects, that the due gradations of colour may be applied to the trees, hills, or other parts, according to the circumstances of distance, light, &c. without running into an unnecessary or unnatural display of such varieties.

Of buildings. By this term artists mean any edifice they represent, particularly such as being of regular architecture, and occupying a conspicuous place in the painting, enter into the composition of heroic landscape: but a country cottage, or a shepherd's hut, so frequently introduced, nay, so requiste in the rural style, are seldom known by this name. Buildings of all sorts are highly ornamental in landscape, whether Greek or Roman, Gothic or more modern; but such edifices, while entire and in a state of perfect preservation, however beautiful or magnificent in themselves, are by no means adapted to landscape representation: they are not *picturesque;* a term better understood than defined, because it stands for a peculiar feeling, born with us, but susceptible of great cultivation and improvement. The following illustrations of the *picturesque*, drawn from the writings of Mr. Gilpin, and assented to by other judges of painting, seem to come near to the truth:—"Objects are most properly picturesque, when they are disposed by the hand of nature or of art, with a mixture of *varied rudeness, simplicity, and grandeur.* A plain neat garden, with little variation in its plan, and no striking grandeur in its position, displays too much of art, design, and uniformity, to be called picturesque. The ideas of *neat* and *smooth* disqualify objects from any pretensions to picturesque beauty. Nay, farther, we do not scruple to assert, that *roughness* forms the most essential point of difference between the beautiful and the picturesque, as it seems to be that quality which makes objects chiefly pleasing in painting. The term *roughness* is here used, although it properly describes the surface of bodies: when we speak of their delineation, we employ *ruggedness.* Both ideas, however, equally enter into the picturesque, and both are observable in the smaller as well as in the larger parts of nature, in the outline and the bark of a tree, as in the rude summit and craggy sides of a mountain. Thus, for example, a piece of Palladian architecture may be elegant in the highest degree; the proportion of its parts, the propriety of its ornaments, and the symmetry of the whole may be extremely pleasing: but if it is introduced in a painting, it immediately becomes a formal object, and ceases to please. Should we wish to give it picturesque beauty, we must use the mallet instead of the chissel; we must beat down one half of it, and deface the other; throwing the mutilated fragments around in heaps: in short, we must, from a smooth regular building, turn it into a rough and rugged irregular ruin. In such a case no painter of taste would hesitate an instant in his choice. Again, why does an elegant piece of garden-ground make no figure on canvas? the shape is pleasing, the combination of the objects harmonious, and the winding of the walk is in the precise *line of beauty.* All this is true; but the smoothness of the whole, though right, and as it should be in nature, offends when presented in a picture. Turn the lawn into a piece

of broken ground, plant rugged oaks instead of flowering shrubs, break the edges of the walk, give it the rudeness of a road, mark it with wheel-tracts, and scatter round a few stones and brushwood; in a word, instead of making the whole smooth, make it rough, and you instantly make it picturesque. All the other ingredients of beauty it already possessed. We seek for the picturesque amongst all the materials which enter into landscape, as trees, rocks, broken grounds, woods, rivers, lakes, plains, vallies, mountains, and distances. These objects in themselves produce infinite variety, and these varieties are undergoing continual modifications, from position, light, and other circumstances incessantly recurring in nature."

Of Waters. Water is to a landscape, whether real or represented, what the circulating blood is to the animal frame; it is its life and soul. The appearances of water are very various: at one time the impetuous torrent overflows its banks, and spreads devastation on every hand: at another the stream tumbles headlong from a precipice, and rebounds as if returning to its former situation, filling the air with vapour; again, as if confined in its too narrow channel, the water gushes out, dividing into a multitude of silvery rills, whose motion and music delight the eye and ear of the observer: here it flows calmly over its sandy bed: there it seems to forget to move, reflecting, as a natural mirror, the objects in its neighbourhood. But, however ornamental and animating waters are, still there are stations where they cannot, with propriety, be represented. It is also one of the most difficult branches of the art, to give a natural appearance to water, with the reflections and other accidents to which it is liable. Reflections and refractions produced by water, are, nevertheless, subject to certain rules in geometry and optics, of which it is not allowed to the painter to be ignorant, and which may easily be acquired, without his aiming at a profound skill in these branches of science. From these reflections and refractions it is that water never presents the images of objects as they really exist, but when it is perfectly still and unruffled; for whenever by the current of the water over even a gentle slope, or by the effect of the wind, the surface is broken into a continued succession of very small waves, whose sides are differently inclined to the spectator's view, then the images of surrounding objects are reflected in so many various directions, that the objects themselves appear broken and distorted, both in shape and colour.

Of Fore-grounds. As it is by the foreground that we are led into the scene of a landscape, the arrangement of this part of the work demands great attention; as a miscarriage in the introduction must have an unfavourable effect on the mind of the spectator, and dispose him to notice, and even to hunt for defects, where, without such disappointment, he might probably have found only beauties. Fore-grounds may be composed in various ways: sometimes as representing the opening of a spacious valley, naturally conveying the eye to the chief objects placed at a distance; at others they are ornamented with flowers or shrubs, beautiful in themselves, and characteristically displayed; figures or other objects, suited to the description of the scene represented. When shrubs and bushes, or trees appear in the fore-ground, they ought to be represented with such a regard to the general truth of their shape, foliage, colours, &c. as to be immediately distinguished from all others: but this attention it is not required to extend to such a degree of minuteness as to resemble the drawings of a professed botanist. Of plants and shrubs introduced

into the fore-ground, some ought to be more highly and correctly finished than others; a practice which not only is founded on the natural appearance of such objects, according to their meeting or retiring from the eye; but which accounts for the indistinctness of other plants, by showing the observer that it is not from want of skill, but from want of a suitable opportunity, that the artist has not exhibited them with the same minute accuracy as he has done the others.

Of Figures. Although historical and other pieces have been imagined, without any regard to the scenery in which they are placed; and landscapes, in a similar way, have been designed, when no particular action was intended to be represented in them; yet it is certain that both branches of painting would be great gainers by a due natural union: landscapes being destitute of animation without figures, and figures without their appropriate landscape being contrary to the laws of natural probability. Figures represented in a state of absolute inaction, are very unfit for the painter, as they seem to have no business whatever in the scene. The best way, therefore, for the painter is to present his figures in such situations and attitudes, that the spectator may conclude, however erroneously, that the figures were the chief object in the artist's mind, and that the landscape was only considered to be a necessary adjunct to the figures. One consideration of great importance is, that the figures be proportionate to the trees and bushes, houses, or other well-known objects near which they are supposed to be placed, that they may appear neither pigmies nor giants, but real beings, in the midst of real scenery. Should the figures, however, be smaller than due proportion requires, the effect will be better than if they were too large, as in this case the surrounding objects will acquire an air of magnitude, one of the sources of grandeur. As the figures in landscapes, properly so called, must necessarily be small, they must be touched with a spirit and animation, which the best judges will commend, even although it should in some degree overpass the truth of natural appearance.

Of Trees. These furnish one of the greatest beauties of landscape, on account of their variety of sorts and forms, in trunks, branches, and foliage; the vigour and freshness of their growth when young, the picturesque effects they produce when old,, and the light airy appearance they present when animated with varieties of graceful or violent motion. The different sorts of trees demand the painter's utmost attention, that they be presented to the spectator with such features as to leave him in no doubt to what sorts they belong; whether oaks, elms, ashes, planes, firs, poplars, willows, &c. &c. Hence arises one of the difficulties in the student's way in executing landscape; a difficulty not to be removed but by a careful and constant study of such objects, as they appear in nature: but, besides this variety in the sorts of trees, even those of the same species are liable to endless variations in their conformation and colouring, from many incidental causes inexplicable by us. From these two kinds of variety the painter is supplied with an abundant stock of materials for enriching his scenes with objects the most agreeable and interesting; at the same time that he is not permitted to plead this boundless variety of nature, as an apology for his want of discriminating accurately their several characteristic features. The multiplied diversity of shapes, or makes of trees, of the position and distribution of their branches, of their bark and foliage, is such as to defy description: but this very variety leaves the painter without excuse, if his produc-

tions possess not that air of truth and nature, without which no landscape can or ought to please. When the young artist has made a multitude of separate sketches, or a *study*, as it is called, of whatever objects, or parts of objects, he thinks may properly appear in his future works, these drawings or copies ought to be arranged under certain heads, or according to the several subjects with which they are connected, in order to be consulted and brought forward, as proper materials for his projected compositions. It is true, that in order to produce a good effect, even with the most abundant supply of the best materials, the artist must be born with sense, genius, and taste; but these endowments may be highly improved by cultivation, observing the practice of the greatest masters, in their choice of natural objects, and their manner of disposing them, so as to produce the most picturesque effects, without seeming to depart from the chaste sobriety of nature. In the prosecution of these *studies* different practices have been followed by different artists. Some have made their designs from nature in the open air, and finished the drawings, but without applying the colours. Others have made their sketches in oil colours, in middle tint, on strong paper, and found a convenience in doing so, as the several colours sinking in the paper, they were enabled to apply one over another, however different it might be. This method, which requires only the use of the pallet, pencils, oil, and colours, answers well for copying natural objects with correctness; especially if, when the work is nearly finished, the painter return to the spot, and conclude his work by a few fresh touches from nature. Other painters have contented themselves with merely drawing the outlines of objects, and washed them over slightly in their natural colours, just to assist their memory. Some have been satisfied with attentively observing such parts of objects as they meant to employ in their compositions, without making any sketches whatever. Others have executed their drawings with pastel and washing together. Some artists have, with more accuracy and patience, returned repeatedly to the place of sketching, to fill up their first outlines, and introduce such varieties in colouring and general appearance, as different lights and states of the weather or other circumstances might occasion. All these methods are good, and may be followed agreeably to the fancy or disposition of the artist; but they require the necessary implements of painting, with leisure and preparation: they are, therefore, not well suited for him who wishes to seize those sudden, unexpected changes which frequently take place in nature from various causes, and which, by their singularity as well as truth, are capable of giving high effect to a painting. In this case the following practice has been recommended as both convenient and useful. Let the painter, provided with a quantity of paper and a black-lead pencil, design slightly but rapidly, whatever he sees extraordinary; and in order that he may make no mistake in the proper colouring, mark the principal parts with characters or figures to be explained at the bottom of the sketch, as far as may be necessary for his recollection.

Thus one cloud may be marked A, another B, a particular light C, a mountain D, a terrace E, and so on. Against similar characters at the bottom, he ought to write the colour of each object noticed, as red, blue, grey, &c. He ought then to take the earliest opportunity of proceeding to his work in painting, that the several circumstances may not slip out of his memory. This method is the more useful, as it not only prevents the loss of an infinite variety of sudden and transitory beauties of na-

ture, but also furnishes the means of perfecting the other methods already mentioned. As nature is continually changing her attire, and putting on a different garb, she must be followed and observed at all times. *Autumn*, however, presents us with the greatest variety of effects. The mildness of that season, the beauty of the sky, the richness of the earth, are powerful iducements to a painter then to exert himself, in laying up materials for improving his talents and perfecting his art. With all these helps, however, it is impossible for the most sedulous observer of nature to see or notice all her varieties: he must, in this case, avail himself of the labours of others who have gone before him. We are told, that even the divine Raphael sent persons into Greece to copy such morsels of art as he thought might be of service to him, and did make use of them to as much advantage as if he had designed them himself. For this conduct Raphael is so far from being censurable, that he deserves to be commended, as setting an example, that artists ought to avail themselves of every method for advancing towards perfection. The landscape painter ought, therefore, boldly to make use of the works of others to gain improvement: for men of superior talents are alone capable of using, and, as it were, adopting other men's minds to their own purposes, or are able to make out and finish what, in the original, was only a hint or imperfect conception. A readiness in taking such hints, which escape the dull and ignorant, makes no small part of that faculty so much extolled---*genius*.

In executing the practical part of landscape painting, the following preliminary remarks may not be unnecessary. That probability may be apparent in the distribution of the several objects of the scene, and of their parts, a knowledge of at least the general principles and most ordinary rules of *perspective*, is indispensable. It is to be observed also, not only for the sake of perspective but of truth, that the leaves of trees are commonly smaller, in proportion as they are raised above the ground, and paler in colour as farther removed from the sources of nourishment. The higher branches are the first to take the various tints produced in autumn. In plants, however, this does not happen, for as their stems are renewed all the year long, and their leaves follow in constant succession, those which first appeared in the lower parts of the stem are likewise the first to decay. These effects, however, must be understood as more liable to take place in some kinds of plants than in others; and nothing but a careful observation of the progress of nature will enable the artist to give an air of truth and accuracy to his works. The upper parts of leaves are commonly of a darker and duller green than the under parts, which often put on a silvery tinge, as may be readily seen when they are shaken by the wind. The green colour predominates when we look up through these leaves at the time they are strongly enlightened by the sun. Although the prevailing colour of trees and plants be green in spring, and yellow or brown in autumn, yet these colours must be so applied as to produce an endless variety of tints, otherwise the piece will appear unfinished, or unskilfully executed. It is, therefore, the business of the painter to correct, and, as it were, reform the general garb of nature, according to the particular season represented, by the introduction of sun-shine and shade, of figures, buildings, water, or other objects, whose varied colours may give due repose to the eye, and a harmonious arrangement to the several parts of the work. The student ought to take every opportunity to examine the

works of the best masters in landscape, that he may catch somewhat of their manner of execution, whether in disposition, drawing, or colouring: and even much of the mechanical part of the practice of painters may be learned by a diligent study of the best pictures; so much so, that it is generally by an intimate acquaintance with the painter's peculiar manner of working, that his original paintings can be distinguished from copies or duplicates. More may be learned by such observation than by any written rules, in many of the principal parts of his art: for what rules can be laid down for ascertaining the forms, dimensions, and proportions of trees, as are done with regard to the human figure, or other animals? The beauty of trees generally consists in the conformation and even contrast of their branches, a sort of capricious variety of nature, in which she delights, and in which Titian, Rubens, and other painters have shown the accuracy as well as judgment with which they copied her productions. Figures, animals, water, trees shaken by the wind, give vast spirit to a landscape; and demand great attention from the artist, that each object and the whole composition, may preserve its peculiar character, to distinguish it from all others of a similar sort; avoiding the two extremes, of a monotonous uniformity of representation, and a licentious or whimsical manner of giving to such objects attitudes and appearances, which, although within the bounds of probability, are not sufficiently common to be considered as justly appropriate or characteristic.

As there are various styles of thinking and composing, so there are various styles of execution. In thought, for instance, there are the heroic, and the pastoral or rural; and in execution there are the bold firm style, the delicate finished style. The bold manner animates the piece, and often atones for many deficiencies in the selection and other important parts of a subject; on the other hand, the delicate polished style finishes and ornaments every minute part to such a degree as to leave nothing for the spectator to wish for, and from that very circumstance often to satiate if not disgust him. The perfection of the art would be, to design and compose with boldness and freedom, and to finish with a minuteness and correctness within the bounds of nature.

This is not the place to treat of the nature and composition of the different colours used in painting, we shall merely observe, that those used in landscapes are chiefly the following:—

1. Fine White	6. Burnt Umbre	11. Lake
2. Common White	7. Ivory Black	12. Indian Red
3. Fine light Ochre	8. Prussian Blue	13. Vermilion
4. Brown Ochre	9. Ultramarine	14. King's Yellow.
5. Brown Pink	10. Terre Verte	

The principal Tints are these:

1. Light Ochre and White	6. Brown Pink and Prussian Blue
2. Light Ochre, Prussian Blue and White	7. Brown Pink and Brown Ochre
3. Light Ochre and Prussian Blue	8. Brown Pink, Ochre, and Prussian Blue
4. The same made darker	9. Indian Red, and White
5. Terre Verte and Prussian Blue	10. Ivory Black, Indian Red & Lake.

The colours generally used for the first coat or the *dead-colouring*, are common white, light ochre, brown ochre, burnt umbre, Indian red, ivory black, and Prussian blue. The principal colours and tints for painting the *sky*, are fine white, ultramarine, Prussian blue, light ochre, vermilion, lake, and Indian red. The tints are a fine azure, lighter azure, light ochre and white, vermilion and white, and a tint made of white, a little vermilion, and some of the light azure. Landscapes are frequently done on a ground, in colour resembling *tanned leather*, composed of brown ochre, white, and light red, which gives a warmth to the shade colours, and is agreeable and fit for glazing. The first part cf the operation of painting is the rubbing in, or *sketching*, which is usually done with burnt umbre, driven with drying oil, and a little oil of turpentine; performed in a light faint free manner, leaving the colour of the cloth for the lights, as that of the paper is left in drawing. No part of the shadows ought to be made so dark as the first lay, or dead-colouring is intended to be, which must be left lighter than the colours to be afterwards applied in finishing. Though the leaves of trees be only sketched or rubbed in, yet the trunks and bodies ought to be in their proper shapes and positions, with the due breadths of light and shade. All sorts of buildings must be done in the same way, the cloth being left for the lights. When there are figures intended to appear in the fore-ground, they should also be sketched in the same way, and left to dry. The *dead colouring*, or first lay of the painting, ought to be without any strong dark, or bright glaring colours; that the effect produced may be better fitted for receiving and preserving such colours as are afterwards to be applied, than to give the full appearance of these colours in the first operation. The first to be done is the sky; then the distances; so working downwards to the centre group, and thence to the fore-ground and parts nearest the eye. In doing this, all the parts of each group, and of the objects composing it, whether buildings, trees, or the like, should be painted at the same time, that they may be all alike advanced for receiving the after operations. After designing the landscape in this way, the student is to begin with the sky, laying it on with a good body of colour, and giving a faint tracing of the forms of the great clouds, more in the manner of the *chiaro oscuro* than with finishing colours; the whiter this first body is left, the better it will be able to receive the proper tints, and give the due relief to the clouds, in the progress of the work. The *distances* ought to be laid out faintly with the dark-shade, with a slight representation of their various lights, that the principal parts may afterwards be introduced with the truest effect. In proportion as the work advances to the centre the shades gradually partake of the colour of burnt umbre. The grounds of the trees should be rubbed in, just enough to give a faint resemblance of their figures and shadows. The shadows must be laid with a clean ground, and lighter than the colours to be used in finishing, and such as may be best suited to the various hues to be afterwards applied. In painting the lights of the landscape, it is safest to use such colours as more nearly resemble the middle tints than the very high lights; and these ought to be left with a good body of clean colour, well suited for receiving and preserving those used afterwards in finishing. This may be done with a few tints, and then the whole should be gone over very lightly with what is called the *sweetener*, in order to soften and mingle the colours in an

agreeable, harmonious manner, to receive the last finishing. By the *sweetener,* artists mean a hair-pencil or brush, with which the strongly marked edges or boundary lines of the different bodies of colours, when first laid on, are gradually softened and blended together, so as to incorporate and glide the one into the other, in an easy natural manner.

The second painting. In this stage of the business the artist begins with the sky, laying in all the azure, with the several colours of the horizon, which must next be softened and blended. He next applies the prevailing colour of the clouds, modifying and finishing it with the higher lights, and other varieties of tint requisite, the whole worked with delicate light touches, and concluding the operation softly with the sweetener. The finishing of the sky seldom succeeds well, unless it be executed all at one painting, as the very tender character of the clouds can hardly ever be naturally expressed, but when all the colours are still moist and flowing, and capable of being properly blended and incorporated together. If the azure and colours of the horizon are laid on with a good stiff body, it will be much easier afterwards to represent the clouds upon them. Such objects as are intended to appear at the greatest distance are commonly laid with the colour of the sky; but such as draw nearer to the eye, and of course become darker, ought to have their parts glazed and scumbled very thinly, using such glazing shade-colours as come the nearest to the prevailing local tints of the group in which the several objects appear. This glazing ought to be somewhat darkish, that the first painting, or dead-colour, may be seen distinctly through it; and on this lay or ground the finishing colours are afterwards to be added. When this glazed ground has been skilfully chosen, and properly adapted to the objects, situation, and other requisite circumstances, the other colours necessary for the lights, and the finishing of the whole, will be easily discovered. In laying these on, however, great care is necessary, lest the glazing be spoiled: the colours ought, therefore, to be very accurately mingled and worked upon the pallet, and then laid on with very light free touches of the pencil.

Glazing, in the painter's language, means the application of a thin superficial coat of clear transparent colour, and is generally practised on the shades. This coat is a composition of the requisite colour, mixed with turpentine, mastic varnish, and linseed oil: at other times painters use only colour mixed with mastic varnish and pale drying oil. These ingredients, smartly shaken together, form a clear substance like a jelly, extremely useful in many parts of the painter's work. This composition is commonly called *megellup.* The most useful glazing colours are lake, terre-verte, Prussian blue, and brown pink. By managing these colours, in glazing, much in the way that Indian ink is used in drawing, and by leaving them very clear and distinct, the better effect will be produced, and the more transparent and beautiful will they appear and remain, particularly when done with good drying oil. Next to these four colours, burnt umbre furnishes a very good warm glazing brown, extremely serviceable in representing broken grounds and the nearest objects in the piece: but the most pleasing colour of all, for the deepest shadows, is the dark-shade, when improved by a mixture of lake. This gives a fine warm colour when used with drying oil, mingling most harmoniously with all the varieties of light and shade, and has an admirable effect when applied on the trunks of trees, and in buildings of every sort.

It is true, in a general sense, that all *colour* is a modification of light, and all *shadow* is a privation of light: but as the rays of light, in passing through, or merely by the side of bodies, undergo various degrees of inflection; and above all, as the atmosphere and surfaces of surrounding bodies reflect very strongly the rays of light falling upon them, such a total privation of light, or absolute shadow, does not exist: nor if it did exist, can the painter hope to succeed in representing it, because no painting substances, nor compounds of substances, can be found which will totally absorb, and not in any degree reflect the lights falling on them: neither would shadows, produced by such substances, were they to be found, be discernable by the eye, which sees only through the medium of light. It may, therefore, appear unnecessary, if not erroneous, to change the dark shade of ivory black, by the admixture of lake, Indian red, or any other lighter colour whatever; because the substances applied to the picture ought to produce the very deepest shadow possible, which, after all, when observed through the medium of the air and light, will assume an atmospherical tint, much lighter than it was the artist's wish to produce.

The colours requisite for the finishing of the second course, are the middle tints, which should be carefully laid over the broadest lights, managing them in such a way as not to cover and injure too much of the glazing. This should be done with a good body of colour, as stiff as can be conveniently managed by the pencil, to preserve the character of the objects. The colours of a middle tint ought also to be of a clean beautiful hue. In this manner it will be easy for the artist to finish the second painting, as he works downward from the sky through the middle group. When he comes to the first group, in which the objects must appear distinct and accurately finished, he should begin and finish the under, or most distant parts, before he touch any of those which come most forward to the eye. This method may be observed all the way down to the last objects of the picture which stand closest to the spectator; at the same time that the painter is at liberty, for good reasons, (such as that a right effect is not produced by his executing one tree over and across another) to leave the doing of the second tree until the first be dry. In doing thin trees near the eye, and of various colours, it will be best to give the under parts time to be well dried before the finishing colours be laid.

The third and last painting. Here it is sometimes requisite to apply an oiling; but it ought to be done with the smallest possible quantity, using a pencil or stump-tool, adapted to the spot to be oiled, that no other may be in the least touched; after which the oiled place must be wiped with a piece of a silk handkerchief, that no more oil may remain on the work than is necessary. An infinite variety of tints are requisite in finishing objects of all sorts, especially in trees, by which a rich harmonious colouring is produced. As green colours are apt to fade and lose their brightness, sometimes turning very dark, it is proper to improve and strengthen them by even exaggerating the lights: and for the same reason great care ought to be used not to overcharge and destroy the beauty of the glazing, lest it become dull and heavy, and consequently dark.

In painting trees near the eye, it is usual to lay on the first colour approaching to that of nature, but not so dark, and more in the mode of a middle tint; following it up with improving the middle tints, and

strengthening the shadows. Last of all, the high lights and finishing colours are to be applied. All this, however, is not to be properly executed at one painting; the best way, therefore, is to do no more than just the first lay with the fainter shadows; when this is dry, then the middle tints and shadows should be touched and improved; and suffering the piece to stand till these last parts are likewise dry, the third and last operation begins, which consists in adding all the lights and the finishing colours, in the most masterly manner the painter possesses. By thus leaving the first and second parts each to dry, the whole work becomes much easier, and more agreeable in the performance, and the colours appear to the greatest advantage; as great part of the work may be done with glazing and scumbling; and in some places no oiling will be necessary. The lights also may be applied with a better body of colour, without any danger of their being mixed and injured by the ground-colouring while wet. What is here observed, regarding the manner of painting trees, is easily applicable to all sorts of shrubs, bushes, &c. The figures in a landscape are the last executed parts of the work; beginning with those in the foreground, and then proceeding to those at the greatest distance; by which means a standard will be obtained for proportioning such figures as may occur in the intermediate spaces, according to their respective situations with respect to the spectator and to each other, and the trees, buildings, or other objects in their vicinity. It is hardly necessary to remark, that the shadows of the figures ought to be of the same colour with those of the connecting group or place where these figures appear.

PORTRAIT PAINTING.

If the excellence of all painting consist in an imitation of nature, this imitation is peculiarly requisite in a portrait, as not only resembling the human species in general, but some individual person, and therefore possessing those particular features and other circumstances, by which this individual is distinguished from all others. To produce this personal resemblance, a judicious selection of these circumstances is necessary; and the painter is expected to chuse the most favourable position of the head, or attitude of the whole body, as well as the peculiar moments of outward indications of the predominant, or at least the most desirable emotions of the mind; that his production may be a correct representation of the whole person he is employed to paint. Every individual possesses some characteristic traits of body and mind, and by seizing these, the artist will have the best chance for producing a good portrait: but in the present state of society, artificial manners have so much usurped the place of natural expression, that opportunities of producing such portraits seldom present themselves to his eye.

The chief parts of portrait painting are the *air* and *identity, colouring, attitude,* and *dress.*

Of the *air,* or more properly the *identity* of a portrait. This relates to the lineaments of the countenance, the head-dress, and the size of the person. The lineaments of the face depend on the correctness of the drawing, and the exact agreement of the several features and parts; all combining to show the face in such a manner that the picture may be a faithful copy of the mind and body of the original. The mere correct-

ness of drawing is not so likely to give spirit and identity to a portrait, as the just arrangement of the several parts, taken at the precise moment when the temper, disposition, or other qualities, are most evidently expressed in the countenance. It is from an inattention to these circumstances, or from an inability in the artist to seize them, that so many portraits, though designed with considerable accuracy, have a cold, inanimate, or unmeaning air; whilst others, less correctly drawn, strike us at first sight with a resemblance of the original. It is of the utmost importance to a portrait, that the parts be well put together. The features must correspond, each contributing its due proportion to the general expression: thus, the mouth must not appear to smile while the eyes are sad, and so on, exhibiting an unnatural and ridiculous air of the countenance. Although the various ways of arranging the hair may properly be considered as a part of *dress*, yet, as it constantly appears to us in conjunction with the face, it is so closely connected with it in our imaginations, that attention to the colour and distribution of the hair becomes a very important part of the artist's business. The head attire of an acquaintance to which we have been accustomed, so much contributes to the likeness, that we scarcely know the person in a different wig, hat, &c. It is, therefore, necessary to take the hair of the head-dress to accompany and set off the face. *Stature* is so essential to likeness in general, that we often recognise a person without seeing his face: it is proper, therefore, to draw the size from the original person, but the attitude ought, if possible, to be left to the discretion of the painter. The common practice in taking a likeness, of making the person *sit*, has many advantages, but it is rather unfavourable to the figure, as the body is apt to sink; and if it be kept up by any exertion, the appearances will be either irregular and dissimilar, at different stages of the business, or the whole will assume a constrained air, than which nothing can be more fatal to good effect in a painting. It has often been a question, whether the portrait painter should attempt, in his representations, to correct any natural defects in his original. Likeness being the essence of portraits, it would seem that we ought to imitate defects as well as beauties, since thus the imitation will be more complete: but the greater number of persons, although they approve this in theory, show evidently that they by no means desire to reduce it to practice, particularly in portraits of their own persons. And here it seems to be but fair, that some complaisance should be shewn to them by the artist; as it is very possible to make a picture resemble the original, without giving any offence: for the likeness consists in the just agreement of the painting with the natural features, so that one may be at no loss to recognise the idenity of the face, and the general character of the person represented. All deformities, therefore, when the air and resemblance may be preserved without them, may fairly be either corrected or omitted, particularly in portraits of women or young persons. Thus, a nose somewhat awry may be restored; a meagre neck, a high shoulder, &c. may be adapted to an agreeable air and attitude, without running palpably into extremes. This, however, must be done with great discretion, lest by endeavouring to correct nature on all occasions, the painter acquire a habit of deviating from his original, and of giving to all his works one general manner; just as by confining himself too much to copy every minute peculiarity or defect, he sink into a little mode of execution, destitute of life and taste.

Of the *colouring* of a portrait. By colouring we exhibit the natural temperament of the person represented, a most essential part of the likeness, and requiring all the artist's skill: for excellence in this part of his art is much rarer than would be, at first sight, supposed. In colouring, the objects are to imitate with precision the natural tints, and to apply them in such a way as, without departing from the natural arrangement in the original, may produce the most advantageous effect. The tints can be learned only from practice, by examining and comparing the colours we see in life, with those by which we wish to imitate them; and the art of employing these tints is to place them beside one another, in such an order as to produce the desired effect, at the same time making the proper allowances for the changes gradually appearing in them, after they have been applied, when much of their glowing freshness will be abated. The painter who does nothing more than represent what he sees before him, will not easily arrive at a perfect imitation: for though his work may, on the easel, appear proper to himself, it may have a very different effect on others, and even on himself, when beheld at a distance. A tint, when near the eye, appears of one colour, but at some distance varies so much as to be confounded with other tints on each side: In order, therefore, that the piece may have its due effect, when viewed where it is intended to be hung, both the colours and the lights must be a little loaded, but with discretion and skill. In this part the artist may learn admirable hints from the works of Titian, Rubens, Vandyck, and Rembrandt.

The tints commonly demand three separate observations: the first is at the person's first sitting down to have his picture drawn, when the exercise and external air may have excited a more lively complexion than is usual with him; the second when he is somewhat composed, and has resumed his ordinary colour; the third, when from weariness, in sitting long in the same posture, the complexion undergoes a change. On this account the natural complexion, somewhat heightened, may be the best colour to be applied to the picture.

In painting the drapery, the artist is to consider, that all sorts and colours of stuffs do not equally suit all persons. With respect to the pictures of men, it it enough to preserve truth and manly expression; but in those of females, whatever delicate or charming beauties they possess, must be placed in the most favourable points of view, while their blemishes or defects are, by some means or other, softened or concealed. Thus a lively bright white tint or complexion, ought never to be set off by a yellow drapery, which would make it look like plaster; but rather by colours inclining to green, blue, or grey, or any others, which, by their opposition, may make the complexion have more of the consistency of healthy carnation.

The colour and tone of the *ground* are of great importance, and must be governed by laws similar to those for draperies: as the ground must be different from the mass it supports, that the objects placed on it may not appear transparent, but solid, and raised above it. This ground must be determined by the colour of the hair: but when this is of a bright chesnut, it is difficult to find a good ground, unless when a curtain, or some other contrivance of the *chiaro oscuro*, or the sky, be introduced. When the ground is none of these, but a plain surface, such as a wall, it has a good effect to represent this surface variegated with a multitude of tints and shades of colour, which not only resembles the

true colour of such an object, but furnishes the artist with the means of assorting his materials, so as to produce the greatest harmony of tints.

Of Attitude and Posture. Persons ought to be represented in such postures and attitudes as are most suitable to their ages, tempers, qualities, and other peculiar circumstances. Thus old men and women should be grave and majestic; and in general women ought to appear with a noble simplicity and modest cheerfulness; for modesty ought ever to be the characteristic of the fair sex, possessing a charm infinitely beyond artifice and coquetry. Attitudes are of different sorts, according as the person is in motion or at rest. Motions are most suitable to young persons, but rest is applicable to all. Motions demand great skill in the artist, not only in the arrangement of limbs, but in seizing such accidental appearances as are the effect of motion, and by which alone motion can be represented in painting; such as the hair and drapery being thrown into positions, which, from observation, we know them to assume, in different degrees of motion. On the other hand, a person at rest is not to appear as entirely inactive, or as one who sits for no other purpose but merely to have his picture made. Figures at rest in the open air, or in a situation where the wind may have access to them, may likewise acquire a share of the animation properly created by motion, by the action of the wind on the hair and drapery. But in whatever situation or attitude the figures are represented, they must appear naturally, and totally devoid of affectation, which produces the same disgust when discovered in a painting, as in the living original; and from this affectation, but too common in the world, arises a great obstacle to the artist's success, in giving correct, and at the same time natural and graceful likenesses.

The following are the principal *colours* used in the *flesh,* from which the tints are made:—

Flake white, or fine white, is the best we have. It ought to be ground with the finest poppy-oil that can be procured: and the defects of this colour are more frequently occasioned by the quality of the oil, than of the white itself. White is a kindly working colour, which comes forward with reds and yellows, but retires with blues and greens. It is the nature of all whites to sink into the ground on which they are laid, on which account they ought to be laid on white grounds.

Ivory black; an exceeding fine colour, which mixes well with the others, and is the genuine shade for blues. It is ground with linseed-oil, and when used with drying-oil and sugar of lead, is a cold retiring colour.

Ultramarine is the finest blue that can be found; it is of a tender retiring nature, and never glares; but is a beautiful glazing colour: ultramarine is used with poppy-oil.

Prussian blue is a very fine kindly working colour. It is ground with linseed oil; but nut-oil seems more proper for this purpose. It should never be used in the flesh, but answers well in the eyes, and in green tints.

Light ochre is a friendly mixing colour, and of great service in the flesh. It is usually ground with linseed-oil, but nut-oil would be better. All yellows are strengthened by reds, and weakened by blues and greens.

Light red (light ochre burnt) mixed with white, produces an excel-

lent flesh-colour. It is clean and beautiful, and works kindly, although too strong for whites, and is apt to grow darker. This colour should be ground and used with nut oil.

Vermilion ought never to be employed, unless it be made of genuine native cinnabar. It will not glaze, but is a fine colour when glazed upon. It is ground with linseed oil, and ought to be used with drying oil.

Carmine is the most beautiful crimson colour that we know, being a middle colour between vermilion and lake. It is a fine working and glazing colour, and ought to be ground with nut oil, but used with drying oil.

Lake is a deep red, but tender, and unites readily with others; as it is not of a strong body, it should be increased with Indian red: and is an admirable glazing colour. It is ground with linseed oil, and used with drying oil.

Indian red is a strong pleasant working colour, but does not glaze well, and falls a little when mixed with white. This red is ground and used in the same way as lake.

Brown pink is of no great body, but it glazes well. In the flesh it ought not to join or mix the whites, to avoid producing a dirty warm colour; therefore their joinings should be blended with some cold middle tint. In glazing shadows this brown pink should be laid on before the other colours by which it is to be enriched. As it is one of the colours employed in finishing, it ought not to be used alone in the first painting. It is usually strengthened with burnt umbre, and weakened with terre-verte; and is ground with linseed oil, and used with drying oil.

Burnt umbre is a good warm brown strong colour, and works well; of great use in painting hair, and mixes finely with the warm shade.

The principal *tints* for the flesh are the following, all formed out of the colours just mentioned:—

The *light red tint*, made of light red and white, is an excellent ground for the flesh: and with the *shade tint*, is employed to make out the flesh, in the manner of the *chiaro oscuro*. As this colour is too strong for white, and apt to grow darker, it ought to be improved by the addition of a little vermilion and white, to suit the fairness of the complexion. In this state it is still called the light-red tint, and should not be confounded with the vermilion tint.

Vermilion tint is only vermilion and white mixed to a middle tint, which is the brightest light-red that can be made; and agrees well with the white, the light-red, and the yellow tints.

Carmine tint is carmine and white mixed to a middle tint. This is the most beautiful of all reds for the cheeks and lips. It is one of the finishing colours, and not to be used in the first painting, but laid on the finishing colours, without mixing with them.

Rose tint is a compound of white and the *red shade*, and one of the most delicate clean tints used in the flesh, for clearing up the heavy colours: in changing it mixes and sympathizes kindly with the others.

Yellow tint is formed of various substances, sometimes of Naples yellow and white; and also of light ochre and white, which is a good working colour. As the ochre is too strong for the white, care must be used in employing it. This tint follows the light-red tints, but ought to be laid before the blues: should too much of it be applied, the ground may be restored by the use of the light-red tints.

Blue tint is composed of ultramarine and white, brought to a light azure; and is a pleasant working colour for blending the gradations. It follows the yellows, and with them forms the greens: with red it forms the purples. The blue tint is of great service in blending and softening the lights, to produce *keeping*.

Lead tint is made of ivory black and fine white, mixed to a middle degree: this is a good retiring colour, and of great use in the gradations, and in the eyes.

Green tint consists of Prussian blue, light ochre, and white. This ought to be used sparingly in the middle tints, as it dirties the lights: it is generally used in the red shadows, when they are too strong, and does not unite well with other colours.

Shade tint is made of lake, Indian red, black, and white, mixed up to a fine murrey colour of a middle tint. It is an excellent ground for shadows, and hence it has its name; with the lights it produces a beautiful clean colour, inclining to the reddish pearl. As it consists of friendly working colours, the shade itself is of the same nature, and may be easily changed by the addition of other colours.

Red shade is made of lake, with a very small portion of Indian red, and is a delightful working colour, and glazes well: it strengthens the shadows on the shade tint, and when wet receives the green and blue tints very agreeably. It is often used as ground for dark shadows.

Dark shade consists of ivory black and a small quantity of Indian red: it mixes kindly with the red shade, and unites agreeably with the middle tints of the dead colouring. It is an excellent glazing colour for the eye-brows and the darkest shadows, and in general one of the best working colours used in painting.

The first painting, otherwise called the dead-colouring, is divided into two parts, the *first lay* or *ground*, and *the laying on the virgin tints*. The first lay is also divided into two parts, of which the one is to work the shadows only, and the other the lights. The work of the shadows consists in making out all the drawing very accurately with the shade-tint, just as if the piece were to be finished in this way alone: and the colour must be laid or driven very sparingly. The lights should be laid with the light-red tint, with the various gradations observed in nature. These colours, when properly united, produce a clean tender middle tint; because, by mixing with the shade-tint, they change to a pearly hue, and when strengthened with the light-red, they imitate very correctly the appearances of nature. In uniting the lights and shades, a long *softener* or *sweetener*, about the size of a swan-quill, is to be used, which will render the colouring more delicate, and produce a proper effect: and the darkest shadows must be gone over with the red or warm shade, in order to give the finishing to the first lay, or dead-colouring. When the warm shade is laid on the shade-tint, it gives a warmer hue: but when laid instead of the shade-tint, the colours it mixes with afterwards are dirtied and spoiled: again, if the red-tint be first laid, instead of the shade-tint, the shadows will appear too red, and of the colour of blood. It hence follows, that although the warm-shade and red-shade are both excellent colours for shadows, yet they ought never to be laid alone, but always after the shade-tint.

So much for the *first* part of the *first* painting: in the *second* part, or finishing of this stage of the work, the first attention must be given to the improvement of the reds and yellows, and next to the blues, to ac-

commodate them to the complexion; remembering always that the blues on the reds make the purples, and on the yellows give the greens. The same is to be done with respect to the shadows, leaving them clean, and not too dark, because in glazing they will become darker. Should the cloth on which the painting is executed be of a dark, or a bad colour, a strong body must be laid all over the shadows, of such a nature as not to sink into the ground, but have a warm hue, a little lighter than nature; so that it may be in the same state of advance for finishing, as if it had been a light ground. The art in managing the dead colouring is therefore to bring it to the same degree of forwardness for the last touches, as if the cloth had been of the most favourable colour. The grounds of shadows in dead-colouring should be such as will best support the finishing colours; that is, it must be clean, and a little lighter than these last, because the finishing part consists in *glazing*, which darkens the colours glazed; and without glazing, their beauty and brilliancy cannot be brought forward. It is, therefore, improper to glaze the shadows in the first painting, instead of laying a body of shadow colours near to, but lighter than the life. When these colours are dry, they may be glazed and touched with great ease and advantage; but if the first painting begins with glazing, the solid colours afterwards laid on it will look dull and heavy. All colours and shadows, therefore, that are to be glazed, ought to be laid with a clean solid body, as then the glazing is most lasting, and has the best effect. Nothing should remain after this operation that can have the appearance of roughness, to hurt the character of the finishing colours: and this may be done by means of a soft tool, when the work is wet, or by a knife, when dry, to remove all roughness or inequalities in the surface of the painting.

The second painting begins with laying on a very small quantity of poppy-oil, which is again wiped almost entirely off with a piece of dry silk handkerchief. The second painting is, like the first, divided into two parts, one called the first lay of the second painting, that is, scumbling the lights and glazing the shadows; the other part is the finishing of the complexion with the virgin tints, and improving the likeness, as far as can be, without loading it. By *scumbling* is meant the practice of going over the lights, where any change is to be produced with the light-red tints, or some other of their own colours, with short stiff pencils, to clear and improve the complexion. This operation, however, must be done with great caution, lest the beauty of the first painting be spoiled. The light-red tint improved is the best colour for scumbling, and in general for improving the complexion: but where the drawing and shadows are to be corrected, it should be done with shade-tint, driving the colour very stiff, that it may be the more easily retouched and changed by the application of the finishing tints. Some parts of the shadows ought to be glazed with a transparent shadow-colour, approaching to the natural hues; but so gently as not to injure the tone of the first painting, the ground of which should always appear through the glazing. In mixing the lights and shades particular caution is requisite that they do not become dead and *mealy*, as it is called, which is the case when they are too much mixed together. When all this is done, the complexion is improved and prepared for receiving the virgin tints and finishing touches. The *second* part of the *second* painting consists in going over the complexion with the *virgin tints*, or those colours which are employed to give the highest perfection of colouring to both lights

and shadows. This operation is performed in the same way as in the second part of the *first* painting, that is with reds, yellows, and blues, blending them together with light delicate touches of the tender middle tints, but without softening. The tints and their grounds must be left clean and distinct, and the farther improvements reserved for another course, lest in attempting to give the finishing touches, before the preceding courses are dry, the hues be changed, and the drawing and character of the parts be spoiled.

The third painting or finishing. The complexion is now supposed to be so far advanced as to need only a few light touches; no oiling is therefore required. The first step is to examine all the glazing, and correct what may be amiss; and where this glazing serves only as a ground or under-part, it is proper to consider what is next to be done, that the alteration may, if possible, be performed at once. This preserves both the glazing and the tints, but cannot always be done, as it frequently happens that no such variety of tints and finishing colours can be brought together and laid on at the same time, without endangering the effect of the whole. In this case it is best to leave off while the work is uninjured, and to stay till the colours are dry, before the few remaining touches are applied, which may be done without oiling, by some free light strokes of the pencil.

Of back-grounds. By a story told of *Rubens,* we are authorised to assert, that, in his opinion the back-ground is of the greatest consequence to the effect of a picture. Rubens being desired to take under his instruction a young painter, the person who recommended him, in order to induce Rubens the more readily to receive him, said that the youth was already somewhat advanced in the art, and that he might be of immediate assistance in the back-grounds. Rubens smiling at this person's simplicity, answered that, if the youth was capable of painting back-grounds, he stood in no need of his instructions; for that the regulation and management of them required the most comprehensive knowledge of the art. The back-ground must be in unison with the figure, so as not to have the appearance of inlaid work, like Holbein's portraits, which are often on a bright green or blue ground. "To prevent this effect," says Sir Joshua Reynolds, "the ground must partake of the colour of the figure, or contain such a mixture as to exhibit in it something of every colour in the pallet. The back-ground likewise determines where and in what part the figure is to be relieved. When the form is beautiful, it ought to be shown distinctly, but when on the contrary, it is uncouth, in shape or hue, it may be lost in the back-ground. Sometimes a light is introduced, to join and extend the light on the figure, and the dark side of the figure is lost in a still darker back-ground; for the fewer the outlines which cut against the ground, the richer will be the effect; as the contrary produces what is called the *dry* manner." Vandyck generally made out the *keeping* of his back-grounds more by the opposition and the harmony of the colours than by the practice of the *chiaro oscuro.* The difference between his manner of treating light and shade, and that of Rembrandt, is very remarkable. Vandyck's usual method was to be very stiff and mellow, and to break the colours of the ground with those of the drapery. This will certainly produce harmony, the principles of which properly belong to the art of colouring: but it is the knowledge of light and shade which gives the astonishing force and strength so observable in the works of Rembrandt. There is

a picture of this artist representing a lady, where he has made the ground just light enough to shew her complexion and hair, which is of a dark brown, in the greatest perfection: the back-ground is a wall, which, near the face, is lighter than the shadows of the flesh: but this light diminishes so artfully in the gradations, that though the part of the wall which surrounds the head is much darker, yet it appears to be of the same colour with that near the flesh. Vandyck, on the other hand, has given relief to the head, by making the ground almost of the same colour with the hair; and although his skill was admirable in breaking the colours of the ground with those of the draperies, yet there appears a sameness in the effect of some of his pictures, where this principle of relief seems to be carried to the extreme.

The principal colours necessary for painting back-grounds in portraits are the following, viz:—white, black, Indian red, light and brown ochres, Prussian blue, and burnt umber; from which the principal tints are formed, viz.—*Pearl,* made of black, white, and a little Indian red. *Lead,* of black and white, mixed up to a dark lead-colour. *Yellow,* of brown ochre and white. *Olive,* consisting of light ochre, Prusian blue, and white. *Flesh-colour,* made of Indian red and white, mixed to a middle tint. *Murrey,* consisting of Indian red, white, and a little black, mixed to a kind of purple, of a middle tint. *Stone-colour,* of white, umbre, black, and Indian red. *Dark shade,* made of black and Indian red only.

Painting of back-grounds is divided into two parts, the first lay, and the finishing tints. In the first lay the learner is to begin from the shadowed side of the head, painting first the lights; thence go to the shadows and gradations, which should be done with a large tool of middling stiffness, in a sparing way, with the dark shades and white a little tinged with those colours requisite to give it somewhat of the proper hue, but nearly of the proper tone and strength. The warm dark shadows ought to be laid before the colours that are to connect with them, by means of the dark-shade and umbre, with drying oil; for if those colours were first laid they would injure the transparency, in which the greatest beauty consists. The more the first lay is driven, the easier it will be to change it with the finishing tints, which may then be laid with the greater body. The second part of the first lay ought to follow immediately, whilst the colours of the first part are wet and flowing, beginning with the lights, and heightening and finishing with warmer colours, accompanied with fine tender cold tints. The lightest part of the ground is nearest to the shadowed side of the head, and generally governs the rest of the ground. It should be done with a variety of light, warm, clear colours, varnishing and losing their strength imperceptibly in the gradations. These ought to be laid with a sort of cloudy touch, and not appear in distinct spots; observing never to conceal too much of the first lay, which is to be regarded as the principal colour. From the lights the next step is to the gradations and shadows; for when the lights are properly adapted to bring forward and support the head, it is not difficult to fall from these into any sort of shadows that may be best suited to the work. The whole must then be blended and softened with a long large tool, which, together with the body of the drying oil, will mingle and sweeten the whole in such a manner as to give it a finished appearance. It is to be noticed, however that, in drying, the tints will sink and lose a little of their strength and beauty. The grounds, whether walls, &c. ought, if pos-

sible, to be finished at one painting; but if any alterations should be necessary they may be glazed with a little of the dark-shade, well driven with drying oil; on which the proper improvements may be made by some light touches of the requisite colours. The dark shadows may likewise be strengthened and improved by glazing, after the figures are nearly finished, lest they should appear too strong——Fresnoy says,

> " By mellowing skill thy ground at distance cast,
> " Free as the air and transient as its blast;
> " There all thy liquid colours sweetly blend,
> " There all the treasures of thy pallet spend,
> " And every form retiring to that ground,
> " Of hue congenial to itself compound."

Scene Painting.

Although this be a particular branch of painting, yet it generally is, and always ought to be united with other parts of art, such as architecture, perspective, landscape, statuary, &c; and for this reason it requires in the artist an extent and variety of knowledge far beyond what is commonly supposed. It is a good practice in this branch to draw the intended scenes by day-light, that they may be the more accurately designed, and that the painter, or his assistants, may have opportunities of examining, at proper distances, the effects produced by the outline and other boundaries, before the work be filled up with colour and shaded; which last part of the process is best performed, for a similar reason, by candle-light, as it is by this light the scene is to be exhibited; and the effects of candle-light, on certain colours, (blue and green for example) as well as on the shading, the perspective, the relief of the figures, and other circumstances of great importance to the intended effect, are too well known to require any illustration in this place. In theatrical decorations the artist ought, as much as possible, to avoid joining imitations of nature with nature itself; that is, he ought never to introduce, as component parts of these decorations or scenes, living men, horses, or other animals, or real trees, fountains, cascades, statues, &c. for such combinations indicate either a depraved taste, or ignorance and want of genius. Another point in which scene-painting is often improperly conducted, is when the landscape, street, house, or other scene represented, does not correspond to the characters, and times of the action carrying on in them. This incongruity is as great an error as any that can be committed in the dress and appearance of the characters, or in any other branch of the costume; and has a great tendency to destroy the effect of the theatrical exhibition.

OF MOSAIC PAINTING.

This species of representation of objects has had its name probably from its being chiefly used by the ancients in adorning their studies, cabinets, or *museums;* and vestiges of it are frequently discovered in this country, as well as in every other where the Romans were established: it is by their writers, commonly called *opus musivum.* Mosaic painting, if it may be so called, is performed with small pieces of marble,

or other natural stone, cut into parallelopipeds, in breadth and thickness resembling a *die*, but twice as much in length. These *dies* are of every variety of colour, and fixed in due order, in a cement applied to the floor or wall of the apartment. The modern mosaic is generally executed with small pieces of half-vitrified paste, of every possible gradation of colour. The first part of the operation is to have a design or drawing of the intended picture, from which the mosaic is to be copied. A cement or plaster is made of hard stone pounded, and brick dust, worked up with gum tragacanth and whites of eggs, which is laid thick on the wall to receive the painting, and only what is sufficient for the work of three or four days is applied at a time, that it may not dry and harden too much for use. The design upon paper is then applied to the plaster or ground, and traced with a sharp point: after which the *dies*, as they may be termed, previously arranged in small cases, according to their various gradations of colour, are lifted with a pair of pliers, and placed in their due situations, one close to another, the artist keeping strictly to the lights, shadows, tints, and colours of the original design. The *dies* are pressed into the cement or ground, by applying a ruler over a number of them in different directions, that their surface may become as regular and even as is possible, by which the effect is much improved. This operation, it is evident, must proceed very slowly; but when it is executed, the colours being incorporated in the substance of the die, reduced by fire nearly to the state of glass, are never to be affected by the air, moisture, or any external accident; and they possess a lustre not to be attained by any other branch of the art of painting. In Rome and its neighbourhood are many curious specimens of this art, in which the colours are perfectly preserved; particularly the famous piece representing three pigeons on the edge of a bason of water, which was described by Pliny. The finest pieces of modern art are to be seen in St. Peter's church at Rome, where, as paintings, either from humidity, smoke of tapers and lamps, or other causes, were liable to be damaged, copies executed in mosaic of this description, have been substituted, in which the design, the colours, the delicate gradation of tints, have been so closely and so skilfully imitated, that, at a proper distance, the eye cannot discover whether what it sees be a painting, or a piece of mosaic. Adjoining St. Peter's was the place where the operation was carried on, and greatly encouraged by the late Pope Pius the sixth. One of the niceties of the art is to compose the dies of such substances as shall, after being exposed to a violent heat, produce precisely the tints required; an operation demanding great skill and attention in those employed to perform it. When mosaic is executed with marble the manner of working is different. The ground is usually a large slab of solid marble, white or black, on which the design is traced, and then cut out with a chissel, to the depth of an inch or more. These cavities are then filled up with pieces of marble of the proper colours, shaped agreeably to the design, and just thick enough to fill the cavities. These pieces are made to retain their places by means of a cement composed of lime and marble dust, or in any other way more agreeable to the choice of the artist. When the figures are thus marked out, the artist draws with a pencil the colours not determined by the ground itself, which strokes being likewise hollowed out with the chissel, the cavities are filled up with a black cement, composed of Burgundy pitch, poured on while hot. What is superfluous is then scraped off

with a piece of soft stone or brick and water; and the surface of the work polished until it assumes the appearance of one solid piece of marble. Admirable examples of this species of mosaic were to be seen in the chapel of the hospital of *invalids* at *Paris,* and in that of the palace of *Versallies.* Mosaic works are also executed with precious stones cut into very thin leaves, and fixed on a stone ground: the operation is performed much in the same manner with the former kinds of mosaic. In France a sort of imitation of mosaic is executed by means of *gypsum* or plaster of Paris. This is well calcined in a kiln, beaten in a mortar and sifted; with this the ground is formed, either entirely, or only laid on a surface of stone. When the ground is to be made entirely of this plaster, it is poured to the depth of five or six inches, into a frame, so made as to be easily taken in pieces; and the bottom of it covered with a linen cloth tightly stretched. When the plaster is nearly dry, the frame is set up on its edge, and the plaster is left to harden, having been previously mixed and boiled up with fine glue and the colour intended for the ground. The design or figure is then traced on this surface, and hollowed out as in marble, being little less hard, and the cavities filled up with other gypsum or plaster, boiled and prepared as the former, of different colours, to suit those of the design. When this operation is finished, the work is polished with soft stone sand and water, then with pumice, and lastly with emery; and the fine lustre is given to it by rubbing it with oil and the palm of the hand.

We are told by the historians of Mexico, that the natives of that country had arrived at wonderful perfection in a sort of mosaic painting, executed with the natural feathers of the great variety of birds, with which that region abounds. The same thing has been done in Europe, as well as with wool and other similar materials.

Painting in Fresco.

Painting in *fresco* is considered as the most ancient, the most speedily executed, and the most durable branch of the art, as well as the most suitable for ornamenting great buildings. From the fragments that have come down to our times, it appears that the Romans worked much in this way; and travellers in Egypt tell us of colossal figures, painted on walls of palaces and temples in that country, eighty feet high. By the discription given of the ground of these pictures, and of the way in which the colours seem to have been employed, they must have been done in what is now called fresco. The durability of this kind of painting is proved by the existence of these works; for no other sort could so long have resisted the effects of the weather, or the rude attacks of the barbarous inhabitants amongst whom they are found. Authors are divided as to the best climate and situation for paintings in this way: some asserting, that at Paris, for example, such works stand longer than in the south of France or Italy, on account of the lower degree of heat: this is as positively denied by others, who affirm that fresco paintings are longer preserved in dry and warm climates than in those that are moist and cold. But other circumstances ought to be taken into consideration, such as the effects of a fire in the apartment where the paintings are; and of the frost, when allowed to penetrate to them; for frost, as is well known, will burst stones, and affect the internal parts

of the bodies on which the paintings are performed, as well as the substances of which they consist. The choice of place where fresco is to be executed is therefore of the highest importance. In a country where frosts are little felt, the best situation seems to be a northern exposure, but in cold climates a western exposure promises to be more favourable; as were the painting exposed to the sun's rays, immediately or soon after the frost, the effect would be very pernicious. Moisture, however, does not appear to be so dangerous to works in fresco as has been supposed, of which we have instances in the ancient paintings rescued from damp places where they had lain covered for many ages, under heaps of earth, and yet have retained their colours in great perfection: and many of which, as those discovered in the ruins of *Herculanum,* overwhelmed by *Mount Vesuvius,* lost their colour soon after they were exposed to and dried by the external air.

In executing fresco paintings, next to the choice of a situation, the choice of the necessary materials is of the greatest importance; as its durability depends chiefly on the ground on which it is executed. For it will readily be perceived, that minuteness of detail in the forms, an extensive mixture and gradation of tints, delicacy of touch, can make no part of the merits of this kind of painting. It cannot support a narrow examination like a work in oil, because, from its nature, it is liable to a hard and rough appearance, which would offend when brought near the eye. Fresco paintings are chiefly employed in palaces, temples, and other public edifices; and in such situations it is preferable to any other, from the size, the boldness of design, and the freshness of colouring of the figures. They have, in particular, an admirable effect in the roof of a dome, and transport the imagination far beyond the limits of the building.

Fresco painting is usually executed in the following manner:—It is necessary to apply to the wall two layers for the ground work: when this is a brick wall, these layers are easily applied; but when it is of stone, holes are made in it, to receive large nails or wooden pegs to hold fast the first coating of the ground. The first layer is made of good lime and a cement composed of pounded brick, or of what is still better, river sand, which makes a surface more rough and uneven than the pounded brick, and therefore better suited for retaining the second layer. The first layer ought to be perfectly dry before the second, on which the painting is to be done, be applied. The second layer consists of lime slaked in the open air, and left exposed for a year to the weather, mixed with river sand, moderately fine, and of an equal grain. This is applied with a trowel to the first layer, whose surface has been previously wetted, to make the two unite, and requires great skill and dexterity in the artist, that the last surface may be made perfectly even and regular. A fine polish is given to this second layer by applying a sheet of smooth paper to it, and again going over the paper with the trowel, to remove even the smallest inequalities which would give a false appearance to what is to be painted on them, according to the position and distance of the spectator. The artist employed on this preparatory work, is to lay only so much ground as the painter can execute in a day; as this kind of painting can only be performed when the ground is fresh laid on and smoothed. When the layers are thus prepared the painter begins his work; but as he must work rapidly, and as there is no time to retouch any of the strokes, he must have by him

large cartoons, on which are drawn, with correctness, and in full size, the figures to be painted; that he may have nothing to do but to copy them on the wall. The cartoons are a number of sheets of large strong paper, either single, or several folds pasted together, as may be most suitable to the painter's purpose. These cartoons are applied to the surface of the wall, and the various outlines, features, &c. are traced on the plaster, by going over the cartoon with a steel point, or merely by pricking small holes through the paper. When in this manner an accurate and speedy drawing is obtained, nothing remains but to execute the painting. The colours are laid on while the layer of plaster is moist, and they ought not to be retouched when dry, with other colours mixed with the white of eggs, gum, &c. as has sometimes been practised; as these last are sure to turn black, and none but such as are laid on the moist plaster retain their hues. The colours commonly used are a white, made of lime slaked a long while before it is employed in the painting, and the dust of white marble; ochres, both red and yellow; verditer, lapis lazuli, smalt, black chalk, &c. all which substances are simply ground down and worked up with water; and most of them grow brighter as the plaster dries. The brushes and pencils used are long and soft, that they may not scratch or raise the painting. The colours ought to be full, and flowing freely from the tools; and great care must be taken that the design be perfect at first, since no alteration can be made after the work is dry, nor any colour added or changed.

Painting in Water Colours.

This stile of painting can only be considered as coloured drawing, in which the white surface of the paper serves for the lights. All the middle tints are done with transparent colours, and of course have no thickness of body on the paper. The shadows are first prepared with Indian ink, and afterwards glazed agreeably to the various tints and tones of the objects to be represented. The tints are composed in the same way with painting in what the French artists call *gouache*, or body colours; but with this difference, that white is never employed, and that the colours are to be laid on very thin. The objects ought to be exhibited more brilliant than they are in themselves, on account of the Indian ink used in the first wash or preparation, which always diminishes the strength of the other colours applied over it. Prussian blue, which has a tendency to turn dark and black, ought to be very seldom used in this species of drawing. The very expeditious manner by which the endless variety of natural objects around us can be thus represented, renders drawing in water colours extremely pleasing and valuable: and it is in this way that many beginners have acquired a knowledge of the effects of colours; studying this branch as introductory to the other classes of painting.

That branch of water-colour painting, called *gouache*, may be considered as having preceded all the others, and is perhaps the most ancient. The colours first used were probably only various natural substances, such as stones, earths, &c. ground to powder and made liquid with water. These preparations, however, were soon discovered to be very imperfect; and to give to them a proper degree of body or con-

sistency, gums of various sorts were gradually introduced into the compositions. Gums, however, being liable, in drying, to darken and change the brilliancy of the colours, experience at last substituted other ingredients for the same purpose. At present the best artists, instead of gum, make use of *double size*, prepared from parchment or fine glove leather; which is not liable, like gum, to change or crack the colour. A small ball of this *size*, put in a glass of water, will be sufficient for every purpose. Many artists have been discouraged by the difficulties of executing this species of painting, which are not to be overcome but by the greatest assiduity and attention. The most common defect is in making the tints feeble and undetermined, or too thick in body, and of a greyish hue, which gives the painting a pale mealy appearance.

In painting in body colours, or in *gouache*, the first thing to be done, is to paste the paper on a board, of mahogany or walnut-tree, taking care that the surface be perfectly even and smooth, that the paper may lie quite flat: on the other side paste another sheet of paper of the same quality, that the board being acted on equally on both sides, may be kept from warping or cracking, by the effect of the atmosphere. In applying the paper to the board, the best paste is made of starch or fine flour, mixed up with double size, or Flanders glue, diluted and purified with vinegar: and to prevent both paper and wood from being worm-eaten, a small quantity of garlic ought to be mixed with the paste. When the board is thus prepared, the outline is to be drawn with a black lead pencil, taking care that the lines are sufficiently strong to resist the application of the first tint. When this is done, the sky of the landscape is to be laid with a tint composed of white mixed with Prussian blue, and a very small quantity of lake, to prevent it from appearing too cold. This tint must be extended very lightly, and without thickness, to the parts next to the horizon, mixing gradually the white, that the strength of the colour may gradually decrease, on approaching the mountains, or other parts that seem to unite and blend with the atmosphere. The mountains are done with the first tint, in which has been mixed a little more blue and lake, so as to render the tint more decided, and give the mountains a relief from the sky which joins them. The lights of the mountains are done with a tint somewhat paler than those of the lower parts on the horizon. In executing the trees nearest the horizon, the first deep tint of the mountains and hills is used, but warmed with a mixture of Naples yellow and brown pink. Prussian blue or brown pink are used to give the different objects their respective hues, according to their several distances, and the planes or elevations on which they appear. In general the rocks and trees. in the first and second distances, are done with brown pink, sap green, and lake, mixed together; more of the brown pink than of the sap green, or Prussian blue, being employed for the trees than for the rocks. The sap green must be used carefully in the trees, for being of a glutinous nature, it will, if suffered to predominate, give a greasiness to the paper, and prevent the second tints from spreading freely. Should, in the landscape, a lake or a river appear, this part of the picture must be so washed as to reflect similar tints on the hills, trees, or other objects that may be in the neighbourhood; and their several contours must be accurately represented on the water. For such parts of the water as reflect the sun's rays, the same tints are to be employed as in painting

the most brilliant clouds. To form the middle tints and shadows, to the reflect tints add a little brown pink, Prussian blue, or lake, according to circumstances; and in the dark or dull parts a little sap green must be added. When the first *wash*, or course, is executed in this manner, then the foliage and other minute parts are to be done, deepening the shades in the proper places. The darkest tint is composed of brown pink, indigo, yellow orpiment, or yellow ochre, as the subject may require. As the work proceeds, the light masses of the trees must be kept more and more bright and brilliant; which is done with yellow orpiment. Rocks are painted with infinite variety of tints, grey, violet, iron-coloured, greenish, and a yellowish green. The grey tints are made with Naples yellow, blue, black, and a little lake, which, when well mixed together, form a very brilliant and transparent grey tint. It is scarcely necessary to warn the artist, that in this, as in all other kinds of painting, white lead should be used as seldom as possible; for it not only loses its own colour, but has a very hurtful effect on all others that come near it. The grey tints are employed in the shadows, as are also those of the iron colour, consisting of brown ochre, burnt terra di sienna, and a little green. These tints may be still heightened by the addition of a little ivory black. The violet tints are generally made with Naples yellow, lake, and blue black. Green tints are composed of blues and yellows: but in mixing these, orpiment ought not to be united with what is commonly called Sanders blue, green verditer, or grass green, because these combinations never produce any steady natural hues. The yellowish green tints consist of yellow ochre, brown pink, and indigo. When the work is thus finished, it must be glazed over with some light transparent tint, to give the several colours their proper union and harmony. The number of these glazing tints will depend on the judgment of the artist, to suit the several degrees of shade in which the several parts are represented. They commonly consist of Prussian blue, lake, and a very little sap green: but no precise rules can be given for proportioning the quantities of the different ingredients, which must be accommodated to the various purposes for which the glazing is intended. In finishing the picture the greatest care is requisite, for preserving the spirit and lightness of the first sketch: for which purpose the tints carried partially over the first colour ought to be only moderately thick, even on the fore grounds or other parts where they are to appear pretty strong.

By a careful attention to these directions the beginner may hope to give to *gouache* a vigour and perfection nearly approaching to the strength and character of oil painting. This art requires a long and assiduous application; but it is a most agreeable study, and is not attended by those inconveniences which almost inseparably accompany painting in oil colours. It requires also great correctness and delicacy; for the colours must be ground down and purified in the best manner, that their particles may be perfectly combined, and the greatest brilliancy and beauty be produced by the different tints. It is likewise of the greatest importance to be able to judge of the nature and mixture of the various colouring substances employed, that no injury may be received from the effects of the air, or of the various vapours and effluvia floating in it. Particular care is necessary with regard to the different orpiments, which ought to be used sparingly, and in general reserved for the most brilliant touches of light.

Painting in *water-colours* is seldom used for historical compositions or figures, which are usually treated in oil: yet it has, nevertheless, its peculiar beauties and advantages. The colours are free from any offensive smell, and are often made to produce very rich and pleasing effects. As it would be impossible to convey by words correct ideas of the various combinations, tones, and gradations of colours, it is evident that the advices here given must be taken in a very extensive sense, and adapted by the artist to the particular circumstances of the intended work. They may, however, serve to point out the principles on which this part of painting are conducted, to be varied agreeably to the effects desired: at the same time that it is to be noticed, the same colours, in the same proportions, will not produce the same harmony, or appearance, when situated near, or in the midst of others of a different sort. The chief materials in painting with water-colours are, gum arabic, pencils, a pallet, commonly made of ivory: but a Dutch tile, or any other well-glazed surface, of a light colour, will serve the purpose; an ivory pallet-knife, because iron or steel is injurious to the colours.

In beginning to paint the artist is to have before him all the colours ready for use; a pallet to mix them on; a paper to lay under the hand to avoid soiling the work, as well as to try the pencils and colours on it; also a large brush or fitch to wipe off the dust when the colours are dry. The colours must at first be laid on thin; to be deepened or mellowed afterwards as may be necessary. The quicker they are laid on, the more equal and the cleaner they will appear. Care must be taken that no dust mix with the colours, for which purpose, the shells containing the colours, and the pallet, as well as the paper, ought to be well wiped before they are used, with the fitch. When the work is finished, or when it is intermitted or laid aside for a time, the pencils should be well cleaned in warm pure water. In painting the face, it is proper to have some carnation or flesh-colour mixed up with gum-water, in a shell by itself: if the complexion be fair, mix vermilion and flake white: if it be dark or swarthy, then add a little masticot, English ochre, or both. The flesh-colour ought always to be lighter than the complexion intended to be represented, because, in afterwards working on it, the tone of the colours will be lowered. In the cheeks and lips, a mixture of lake and red lead, or carmine, as may be most suitable, may be used; and indigo, or ultramarine with white, will answer for the veins, the skin below the eyes, or other parts where a blueish tint is required.

In executing landscapes with water colours, at first a dead-colouring must be laid over the piece, as smoothly as can be done, leaving no part uncovered, and performed with a bold hand: this, although apparently coarse, will afterwards produce a good effect: and such an appearance must not discourage the artist; for this roughness may easily be softened down, by the gradual application of the other colours, and the due heightening or lowering of the shadows. It is proper, in some places, to lay on strong touches, bringing them all equally forward, tempering and sweetening the colours with a pencil sharper than the former, that no spots or hard edges of the original touches may remain, but that all the shadows may be soft and smooth, gliding and blending gently into one another.

No part of the work ought to be carried far on before the others; but the whole should be brought up together as nearly as possible. When

the dead-colouring is prepared, the first thing to be done is, the painting of the distances and other places where the lightest tints are to appear, such as the sky, the sun-beams, &c.; then come the yellowish rays of light, executed with masticot and white; next the blueness of the sky, with ultramarine, bice, or smalt alone; the colours deepening as the parts rise up from the horizon; unless the atmosphere be charged with tempests. The tops of the most distant mountains are wrought so faintly as to seem to lose themselves in the air: the same rules apply to all other objects at a distance, where they can be but imperfectly and confusedly observed. In colouring trees, boughs, branches, &c. the dark shades are first touched in, and the lighter leaves, &c. are to be raised above the darker; the uppermost of all to be done the last. The extremities of the leaves are to be touched very lightly; and the darkest shadows set off with sap-green and indigo.

A branch of water-colouring is the method of *tinting prints*, in which regard must be had to the quality of the paper on which the prints are executed; for this is sometimes of such a nature that ordinary water-colours, and even body colours, will sink into it, unless previously prepared with a solution of alum, or with some other strengthening substance. The strength and consistence of the colours to be applied to the print must be proportioned to the quantity and nature of the ink on the paper. If it be intended only to stain the print, the engraved parts will answer well for the shadows, and to preserve the keeping of the drawing: but when the print is to be highly coloured, the engraving, although necessary to guide the placing of the colours, may often be kept down, and in some degree concealed by the body of colour. Whites ought to be left out wherever it can be done, as in the lights, or other parts of a tint approaching to the lights; the colours applied being so thin and transparent as to supersede the necessity of introducing white colours. In the same way black ought to be left out, or if indispensable, it should be used sparingly and as gently as possible. In doing the broad lights and shades, the same methods of working and mingling the colours must be adopted, and neither white nor black admitted, without an absolute necessity, arising from the general tone of the engraving and colouring of the print. The outlines of the several objects must be softened down by the colouring, that the sudden hard effects of the engraving may be kept from the eye. Prints are likewise first washed with simple water-colours, and afterwards finished with body colouring, which has a very good effect.

Drawings may also be *tinted* in the following manner:—Sometimes they are outlined with a black-lead pencil, and stained; the sky and distances in the landscape are done over with a thin wash of colour; and the ground and front objects with body-colours; the whole is then wrought up to proper effect with stronger colours alone, or united with Indian ink. At other times drawings are more completely outlined and washed with Indian ink; after which the whole is finished with the requisite colours. Drawings, performed with colours alone, seldom have a good effect, their glare destroying that repose and harmony without which no representations of natural objects can please. In whichever method drawings are done, the lights require more finishing than the shades; in which a broad manner of pencilling has usually an excellent effect; and by a due attention to the management of the middle tints, the beauty of the drawing will be fully attained.

Flower Painting is one of the most agreeable branches of the art, not

only on account of the splendour, the variety and beauty of their colours, but by reason of the little time and labour requisite in executing them. It is not, however, to be supposed, that a certain degree of application is not necessary for acquiring skill in this elegant and delightful part of painting; but only that the same rigid correctness in designing and colouring is not expected in representing a flower, as in a face, or a figure. A face is utterly ruined if the artist paint one eye larger, higher, or lower, than another; the mouth too small, the nose too large, and so on with the other parts. In flower painting slight errors of this sort are not of importance, because the varieties in form, colours, and distribution of parts are, in nature, so multiplied, that deviations from the truth of the object must be very gross indeed, before they can be liable to censure. To acquire some proficiency in painting flowers, nature must be constantly and carefully studied, endeavouring to discover among the colours on the pallet, or in the shells and cups, such original or compound tints as will come the nearest to the real objects. Much useful instruction may also be obtained by studying and imitating the best drawings or paintings of flowers, to learn by what practices and arrangements of colours the various tints of the original may be best imitated.

In general flowers are drawn and laid in the same way with all other figures; but the manner of completing and finishing them is different: for they are first formed by large strokes and traces made and turned in the way the smaller strokes are to be placed in the finishing, which is done by very fine small strokes, without cross-hatching or dotting, unless, as is the case in some kinds of flowers, the surface of the natural object be spotted. These very fine small lines must be repeatedly gone over with the pencil, until all the parts, both dark and bright, have received their whole force. As an example of flower-painting it will be sufficient here to show how roses are done. When the contour and several leaves are sketched, if it be for a red rose, trace these outlines with carmine, touched with a very pale lay of carmine and white. Then the shadows are to be done with the same colours, but with less white: afterwards with carmine alone, strengthening it more and more by repeated touches, according to the darkness of the shades. This is performed by large strokes of the pencil at first, and finished by finer strokes of the same colour, all lying precisely in the same direction and inclination with the leaves of the rose you copy, or with the strokes of the engraving, if you follow a print: taking care to blend the dark and light parts, heightening the brightest parts of the leaves, and illuminating them with white and a little carmine. The hearts of the roses are made darker than the rest; and a little indigo must be mixed with the other colours, for shading the first leaves, when the flowers are full blown, to give them an air of being somewhat decayed. The best dead-colouring for the seed is gamboge, mixed with a little sap-green for the shadows. Variegated roses, or those streaked with different colours, ought to have the ground paler than others of one colour, that the streaks or variegations may be the more apparent. These are laid on with carmine, darker or lighter, according to the point of light falling on or reflected from the leaves of the flowers. White roses are laid with white, and formed and finished in the same way with the red: making use of black, white, and a little bistre: the seed is shown more yellow than that of the red rose. Yellow roses are painted by applying a lay of masticot, and shading them

with gamboge, gall-stone, and bistre; the brightest parts heightened with masticot and white. The stalks, leaves, and buds of roses, of all kinds, are formed with verditer, in which is mixed a small proportion of gamboge and masticot; and for the shades sap-green is added, diminishing the other colours as the shades grow deeper The leaves have more of a blue tinge on the outside than on the inside, and therefore must be dead-coloured with sea-green, or sap-green mixed with the shade-green; and the fibres on the outside must be made brighter than the ground, but those on the inside darker. The prickles upon the buds of roses are painted with gentle touches of carmine laid in different directions; and those on the stalks are formed with verditer and carmine, and shaded with carmine and bistre; the lower part of the stalks being made redder than the top

Of Miniature Painting

Miniature painting consists of very small lines, or rather points or dots, done with very thin simple water-colours, on vellum, paper, or ivory. Paintings of this sort are distinguished from other kinds, by the smallness and delicacy of the figures, and the lightness of the colouring; and therefore require to be nearly examined.

The colours principally used in miniature painting are these:

Carmine	Gall-stone	Leaf gold and silver
Lake	Yellow ochre	Genuine Indian ink
Rose pink	Dutch pink	Bistre or wood soot
Vermilion	Gamboge	Raw umber and burnt
Red-lead	Naples yellow	Sap-green
Brown-red	Pale masticot	Verdigris
Red orpiment	Deep yellow masticot	Flake white
Ultramarine	Ivory black	Crayons of all colours
Verditer	Lamp black	Gold and silver shells
Indigo		

Where writing is to appear through the painting, the following transparent colours are used, viz.

LIQUID.

Lake—Blue—Yellow—Grass-green—Dark-green—Purple—Brown.

As colours formed from earthy or mineral substances, however well they may be ground and prepared, can never be entirely freed from a certain grit or sand, and are thereby unfit for the delicate execution of miniatures; they may be made to give out the finest parts of their colour by diluting them with the finger in a cup of water. When the substances have been well steeped and mixed, they are allowed to settle, and the clearest part of the liquid poured off into another cup, there to dry, and to be afterwards mixed with a little gum-water, when required for use.

By mixing a little of the gall of an ox, of a carp, or of an eel, particularly the last, with the green, grey, black, yellow, or brown colours,

any greasiness in them will be entirely removed, and they will acquire a beautiful brightness and lustre. This preparation makes the colours stick better on the vellum, and prevents them from scaling. These colours are commonly diluted in small ivory cups, or sea shells, with water in which gum arabic and sugar candy are dissolved. To know whether the colours be properly gummed, the artist has only to give a stroke of the pencil on his hand, or a piece of paper, &c: if the colour, when dry, chaps and scales, there has been too much gum used; and, on the contrary, if the colour can be rubbed off with the finger, too little has been mixed with it. Too much gum makes the colour hard and dry; and when the painter wishes to give to his colours a greater darkness than they naturally possess, he has only to add a greater quantity of gum than would be requisite for other purposes.

The pallet used in miniature painting is of very smooth ivory, and about the size of the hand, on which the colours for the carnation, or naked parts of the picture, are ranged in the following way:—the middle of one side of the pallet is covered with a large quantity of white, being the colour most used: and round the edges, beginning at the left hand, are these, viz. masticot, Dutch-pink, orpiment, yellow ochre, green, blue, vermilion, carmine, bistre, and black. The green here mentioned, is a composition of equal quantities of verditer, Dutch-pink, and white; and the blue is made in the same way, with ultramarine, indigo, and white, worked to a very pale hue. On the other side of the pallet, white is spread in the middle, and the other colours necessary for the draperies, or other parts, are arranged around it.

As the delicacy of this work depends much on the goodness of the pencils, great care is requisite in selecting them. In order to make a good choice, wet the pencil a little, and if the hairs keep close together when turned on the finger, making but one point, the pencil is good; but if they do not keep close, and divide into different points, some longer than others, the pencil is good for nothing. The hairs may likewise be too long, feeble, and sharp-pointed: in this case they ought to be shortened and blunted with a pair of scissars. Different sorts of pencils ought also to be provided, the larger for laying the grounds, or dead-colouring, and the small ones for the finishing. It is necessary in working to put the pencil just between the lips, moistening and pressing the hairs together with the tongue, in order to give them a compact point, and to take off a little of the colour when the pencil is too full. There is no danger in this practice, from the qualities of the colours, excepting in the use of orpiment, which, being a combination of the calx of arsenic with sulphur, might have hurtful effects, were it received inwardly in considerable quantities, which never can be the case in miniature painting. The practice here recommended is especially necessary in doting and finishing, particulary in the carnations, that the touches may be neat and clear, and not too much charged with colour. In doing the draperies and other parts, it is sufficient to draw the pencil to a point on the edge of the shell, or upon the paper employed on the picture to support the hand.

The light is of great importance in this sort of painting; it ought to enter the room by only one window, and the table and desk ought to be placed near it, in such a position that the light may come in on the left hand, and never in front, or on the right. In working, the first thing to be done is the dead-colouring, laying on the colours with

free strokes of the pencil, in the smoothest manner possible, as is practised by painters in oil; but without giving it all the strength of the finishing: that is, the lights must be a little brighter, and the shadows less dark than they are ultimately to be made; because in dotting on them afterwards, the colour is always strengthened, and would thus at last become too forcible. *Dotting* is performed in various ways, and most painters have particular methods of their own. By some the dots are made round, by others oblong; some artists again hatch with little light strokes, crossing one another in all directions, until the work at last has the appearance of being done with dots. This last method is the most expeditious, as well as the boldest, and ought to be practised by all artists, in order to acquire the habit of working in a soft and plump way, by which the dots are, in some measure, lost in the ground, and no more of them is seen but just as much as to give the work the look of being dotted. The hard dry manner of working is the reverse of this, and ought never to be used. It is done by dotting with a colour much darker than the ground, and when the pencil is not well moistened, which makes the piece appear rough and uneven. The colours should likewise lose themselves in one another, in such a way, that their joinings shall never be observable; they ought, therefore, to be allayed and softened by delicate touches of another colour partaking of both. When the piece is finished they may still be enlivened by some small touches on the extremities of the lights, with a colour still lighter, which must be lost and drowned with the rest.

Crayon Painting.

Painting with crayons or chalk is in its nature so little durable, that it is, in some respects, a pity that eminent talents should be employed in the practice of it. It may, however, be extremely serviceable in taking a portrait or a landscape, when expedition is required, to be afterwards executed in a permanent manner: some observations on crayon-painting may, therefore, be very useful.

By *crayons* we understand, in general, all coloured stones, earths, or minerals, and substances used in drawing and painting in *pastel*; whether these substances are used in their original consistence, and only cut into long, narrow slips for use, or beaten and reduced to a paste with gum-water. The red crayons are made of red chalk, or bloodstone; the black crayons of black-lead and charcoal, sawed into the proper shape. Crayons of all other colours are compositions of earths reduced to a paste. These several substances, or compositions of colours, must be cut into the proper size, after they are prepared, that they may be rolled into pastels for the convenience of using them. The crayon is formed on the left hand, with the ball of the right, first into a long cylinder, and then tapered to a point at each end. When the composition is too dry, it is moistened by dipping the finger in water; and when it is too wet, the composition must be again laid on the chalk, or other dry materials, that part of the moisture may be absorbed. In rolling crayons no time should be lost, and when they are finished, they are, if necessary, to be again laid in the chalk, to be brought to a proper degree of dryness. When a set of crayons is completed, they are to be arranged in classes for use. This is most conveniently done in a set of shallow drawers, divided by partitions, in which the crayons are disposed according

to the several gradations of light; the bottom of the drawers being covered with bran for the crayons to lie on, without being broken or dirtied. A box for use at any time may be about a foot square, and contain nine partitions. In the upper corner, on the left hand, for example, may be placed the black and grey crayons, which are most seldom used; in the second partition the blues, in the third the green and brown. In the first space of the second row the carmines, lakes, vermilions, and all deep reds: in the middle partition the yellow and orange, and next the pearly tints; which, being very delicate, ought to be kept perfectly clean, that their shades of colour may be readily distinguished. In the lowest row of partitions, the first may contain a piece of fine linen rag to wipe the crayons when in use; the second all the pure lake and vermilion tints; and the last partition may be filled with all those tints which, from their nature, as compounded of many others, cannot be reduced to any of the former classes. Although the object of the artist be the same, whether he paint in oil, in water-colours, or in crayons, namely, to give a correct imitation of nature; yet each class of painting has its peculiar rules and modes of working: thus painting with crayons requires, in many respects, a different treatment from that with oil colours; because all colours used when dry, are naturally of a warmer complexion than when they are wet with oils, &c. Hence it is, that in order to produce a rich effect, a much greater proportion of *cooling tints* are requisite in crayons than with oils, &c. and to an inattention to this circumstance may be attributed the failure in crayons of otherwise eminent painters in oil-colours. In painting with crayons, the student is to be provided with strong blue paper, the thicker the better, if the grain is not too rough, or full of hard knots. Such knots, found in even the best paper, must be levelled down with a penknife or razor, and then the paper is pasted down very smooth on a linen cloth, previously strained on a wooden frame of the requisite size: on this frame the picture is to be executed, although it answers very well not to paste on the paper until the subject be all dead-coloured. The paper, when dead-coloured, is laid on its face on a smooth board or table, and then the back part is brushed over with paste, and the frame with the strained-cloth is laid on the pasted side of the paper, which adheres to it, and being turned up, is gently and neatly pressed to unite in all parts. When this paste is perfectly dry, the artist may proceed with the painting, in which the pasting renders considerable service; for the crayons will adhere better to the paper after than before that operation, and consequently give the picture a firmer and brighter body of colour. When painters want to make a very accurate copy of a picture, they commonly use tiffany, or black gauze, strained tight on a frame, which is laid flat on the subject to be copied, and on the tiffany or gauze, with a piece of drawing chalk, they trace all the outlines and other principal parts. The canvass on which the copy is to be painted is then laid flat on the floor, placing over it the tiffany with the chalked lines, and brushed over with a handkerchief, by which means the lines are correctly represented on the canvas. The same method may be used by the crayon painter; but, in copying a crayon painting, he must observe the following rules, on account of the glass: the picture being placed on the easel, the outlines are to be traced on the glass, with a fine camel-hair pencil, dipped in lake ground with thin oil; this tracing must be done with the greatest care and accuracy. Then take a sheet of paper of the same size, and

apply it to the glass, passing the hand gently over it, by which means the colour will adhere to the paper. Wherever this colour appears, the paper is to be pricked with pin-holes, as close as possible to each other; and the sketch is then placed over another sheet of paper, on which the crayons are to be used. Next, with some fine powdered charcoal tied up in a piece of lawn, rub over the pricked lines, and you will have an exact outline on the second; which must be carefully preserved until the whole be drawn over with chalk composed of whiting and tobacco-pipe clay, rolled like a crayon, and pointed at each end.

In painting from the life, it is best to make a correct drawing of the outlines on a separate paper, in the proper size of the intended picture; and this may be again traced, as above-mentioned, because false strokes of the chalk will prevent the crayons from adhering to the paper, owing to a certain greasy quality in the composition. The young artist will find a sitting posture the most convenient for painting with crayons, holding the box of colours on his knees. That part of the picture on which he is at work should be somewhat lower than his face, otherwise the arm will be fatigued by being kept in too elevated a position. The windows ought to be darkened for at least six feet above the ground; and the subject to be painted should be situated in such a manner that the light may fall with every advantage on the face, avoiding too much shadow, which seldom has a good effect on portraits, particularly when the face possesses much delicacy. In other parts of his work, respecting the attitude, age, and manner, back-ground, embellishments, &c. the observations suggested, when treating of portrait-painting in general, may be attended to in working with crayons. When the whole head is covered over, or dead-coloured, the whole must be sweetened and blended together, by rubbing it over with the finger very lightly, taking care to wipe it clean in passing from one colour or tint to another: but this sweetening and softening has its bounds; for, if it be carried too far, the work will assume a meagre look, and have more the appearance of a drawing than a solid painting, where nothing but a good body of colour can produce a rich effect: this renders it sometimes necessary to lay on a fresh quantity of crayon. When the head is tolerably advanced, the back-ground is to be begun, but in a different way, for it is laid on very thin, and rubbed in with a leather stump. The parts bordering on the face should be almost free from colour altogether, which will give a great relief and air of body to the head, and leave it in the artist's power to finish the hair with freedom and delicacy.

The greatest difficulty in working with crayons is to execute the eyes, where every part is to be done with the utmost delicacy, to have a correct finished appearance, combined with breadth and freedom in the touch; for which reason the crayon, instead of the finger, should be chiefly used in softening the colours; and a fine point may be obtained from the minute parts, by breaking off a bit of the crayon. When the eye-lashes are dark, carmine and brown ochre, or carmine and black are used; and the corners of the eye are done with light touches of carmine, lake, and vermilion; observing always, that too much red here, or in any other part of the eye, gives the appearance of soreness, and has an offensive effect. The pupil of the eye is done of the purest lamp black, and between it and the lower part of the iris, the light is strong, but carefully diffused round the pupil, and lost in the shade. When the eye-

balls are thus advanced, a bright speck is made with pure white crayon, sharpened or broken to a fine point.

Draperies.—Black, dark blue, purple, pink, and all red draperies, are first touched with carmine, to give a brilliancy to the other colours; then the middle tint, excepting in the masses of shade, which are to be laid at first as deep as possible: these softened with the finger in working will represent the broad folds, to which the smaller folds are afterwards to be added. These smaller parts are done with light and dark tints, working as much with the crayon, and as little with the finger as possible; the last stroke in each fold being done entirely with the crayon, and never touched with the finger or sweetener. In doing the reflected lights the touch with the crayon will be too harsh, therefore the finger is to be used, as reflected lights are always less distinct and marked than direct lights. In general, the reflects must partake of the colour of the reflecting objects. When the drapery is blue, the reflects must be of a greenish cast; in a green drapery they are yellowish; in yellow of an orange tint; when red the reflections are of the same colour, inclining to yellow; black gives a reddish reflection; and purples generally produce a reddish tint. It is to be observed, that whatever may be the colour of the drapery, the reflections on the face must partake of it. Linen, lace, furs, &c. are to be done with the crayon, and sparingly touched with the finger, excepting sometimes in furs; and all are finished entirely without any fingering.

The methods here recommended have been followed by many celebrated painters with crayons: but a knowledge of, and ability to execute each separate part of a figure with brilliancy and effect, will prove insufficient to form a complete painter, unless he can also unite these parts together, by correct drawing, propriety of light and shadow, and harmonious combination of colouring. In order to acquire this qualification, the young artist should never finish any one part in particular, but bring on the whole piece at the same time, stopping frequently and examining his work at different distances, or taking the opinion of sensible friends, who are no artists themselves, to discover the due connection of each part with those around it, and with the whole composition. The neglect of those precautions has occasioned the failure of many performances, arranged and begun in a very promising manner

To what has been said on this subject may be added the following short observations furnished by an eminent *amateur* of crayon painting:—

Of all modes of painting, that of crayon or pastel is the easiest and most convenient. You may paint in this way on paper, on cloth, or on vellum. *Rosalva* and *La Tour*, who excelled in this way, painted on a blue paper made in Holland. The blue and grey papers made in England are also well adapted to this purpose, and have the advantage of requiring no preparation before they are used: but no glossy paper ought ever to be chosen. In using paper, it is to be pasted on a piece of linen, or fine canvass, free from knots, and stretched tight on a frame; this paper must not be rough nor glossy, and on it paste another sheet or sheets of paper, on which the drawing is to be executed. In using vellum you must select a sheet that has been well cleaned from grease, and as much as possible of an equal thickness in ever part: if it be greasy the colours will not adhere to it, but fall off in the course of working. The smooth side of the vellum must be damped, and then stretched on a frame with

flat nails, and the painting done on the other side, which is the roughest. The celebrated French artist, *Liotard,* always painted on vellum. When you wish to make use of cloth, it must be nailed neatly on the frame; it must be free from knots or other roughness, and fine, but sufficiently strong to bear the proper stretching; and small thin wedges should be provided to introduce between the frame and the edges of the cloth, to stretch and tighten it, as it happens to give way and slacken. The next thing to be done to the cloth, is to lay on a preparation of the best Flanders-glue and pumice, finely sifted. This mixture is to be boiled, and immediately laid on the cloth with a large brush, such as is used in working with water-colours. The usual proportion of these ingredients is half a stick of Flanders-glue, two table-spoonfuls of ground pumice, in a pint of water. When this paste is quite dry, before you begin to paint, rub the surface over with a piece of pumice, to make it smooth and even: but this is to be done very lightly, lest, in rubbing, you take off the glue, and lose the benefit of the preparation. In preparing either cloth or paper, it is better to put in too little glue than too much; for an excess in this ingredient will render the application of the colours very troublesome and difficult. It is to be noticed, that this preparatory mixture will not answer for a second painting, after it has been allowed to cool, even were it boiled over again. The success of this kind of painting depends on the quality of the crayons, which ought to be of a brilliant tint, but tender and corresponding with those of nature, or of the piece from which the copy is made. When the paper, vellum, or cloth, are sufficiently prepared, begin the sketch of the picture with a dark crayon, and correct the outline with one of a reddish brown, using another crayon still darker, for any additional alterations or corrections that may be necessary. If you wish to efface any part, whether finished, or only sketched, first rub off the colour with a linen-cloth, and then with the finger rub on the place a little ground pumice, or pumice that has been finely sifted through a piece of silk. Then blow away the pumice, and resume the operation with the crayons, as at first. There is this difference between painting in oil-colours and with crayons, that for the first it is necessary to arrange the various tints upon the pallet, before you begin to apply them to the canvass; but, in crayons, it often happens that several tints are laid one upon another, in order to produce, by the blending of these hues, the colours and tints required. The common fault of those who begin to paint with crayons is, that they use too little colour. It is true, that in executing any object, a head for instance, great skill is requisite in selecting the tints; but when you discover that you have already obtained the desired effect by their combination, the colours must be laid on with freedom, and without sparing the quantity for fear of laying on too much. When the whole piece is sketched in, so as to produce an effect when placed at a distance, which can happen only when the lights, shadows, and reflections are properly arranged, you must examine whether there be a sufficient body of colour laid on, to allow of their being blended and sweetened with the finger; and, if this be the case, it must be done with the model from which you work before you. When the colours and tints are properly mingled in this manner, compare the whole with the original, or model, and make the necessary alterations.

In blending the colours, you must be careful to preserve the freedom

and spirit of the first draught, or outline, otherwise you will run a risk of losing what most contributes to the likeness, especially if the person on whose picture you are working has much vivacity in his countenance or manner: for, by the fatigue of sitting long in the same posture, the muscles become relaxed, and the whole face assumes a different air from that which appeared at the beginning of the work. With persons of a more sedate temper, there is less to be feared, as their muscles undergo less change from their first position. When the whole of the head is properly blended and sweetened, you proceed to finish the picture. Having examined each part separately, then give touches in different places, in order to produce general harmony, concluding by the strongest and most spirited touches, to give expression, relief, and truth to the piece; but these last touches are never to be blended or softened down into one another, which would destroy all their effect.

It is of great importance in crayons, as well as in all other sorts of painting, to see a good artist at work, to observe his methods, and to attend to his practice and advice, particularly respecting such colours and tints as are apt to fly or change in mixing. The following rules for fixing crayon and other colours will be of service to the young painter. In order to succeed in this operation, the picture should be placed vertically, or rather a little inclined from the perpendicular, upon the easel, or a chair, or against a wall, to keep it steady. A pocket-brush should be provided, with the hairs of a middling length, and a small iron-rod, six or seven inches long of a triangular form, bent at one end. Then take a pint of the clearest water, into which are to be put two large pieces of the best isinglass, cut very small, to be placed in a sand-bath, until the isinglass be quite dissolved; then strain the liquor through a piece of fine linen, to purify it from any grosser parts. When this is used, it is poured into a saucer, and mixed with twice its quantity of the best spirits of wine. While the mixture is about milk-warm, dip the brush in it, and pass it several times over the bent end of the small iron rod, drawing it towards you, so as to press the hairs together; this forces the greatest part of the liquor to fall off, and leaves the hairs only moistened; then holding the hairs of the brush towards the picture, at a distance of eight or ten inches, apply to the hairs the bent end of the rod, and drawing it towards you, the several hairs, as they escape and return to their original position, will throw off the moisture adhering to them, and thus produce on the painting a sort of imperceptible shower, which will penetrate the crayons, and fix them to the canvass. Whenever the brush is dry, it is again dipped in the saucer, and the operation is continued, beginning at one corner, until the whole surface has been done over. When the whole has been moistened with this shower or dew, let it dry, and then repeat the operation twice more, if you think it has not sufficiently been done at first. The purpose of this is merely to unite the several particles of the crayons, and thus, in some measure, to prevent their being rubbed off by any accidental touch. As crayons will not bear to be rubbed, it is an error to suppose that they can be varnished, which would utterly confound and change the colours. There are, however, many crayon-paintings which cannot be fixed in this manner, owing to the glue, pumice, or other substance that may have been introduced; or from the sketch having been varnished: the application of this shower or sprinkling may nevertheless be useful in giving fresh brilliancy to the colours of the picture.

Painting in Enamel.

Enamelling, a corruption of the French words *en émail*, is the art of applying enamel on various metals, such as gold, silver, copper, &c. and of executing sundry works with it, by means of fire, or the lamp. The enamel is composed generally of vitrified substances, interspersed with others not vitrified; so that it possesses all the properties of glass excepting its transparency. The basis of all enamels is a pure glass, ground up with a fine calx of lead or tin, prepared for the purpose, with the addition commonly of white salt of tartar. These ingredients baked together, with powders of different colours, afford enamels of all kinds. Of all the modes of painting, none is more solid and durable than enamelling; for time, which consumes all things, has no sensible effect on the beauty or the brilliancy of this work: it may be observed also, that no species of painting unites so many difficulties in the execution. The process is performed on metal plates covered with a white coat of enamel. Gold is often used for this purpose; but copper, when well managed, is almost as good. These plates are made concave on one side, and convex on the other; and are usually round or oval: if they were flat, there would be a risk that the enamel might fly off in undergoing the action of the fire or lamp. The convexity of the plates, however, must not be considerable, for this would injure the effect of the painting, as the sight could not rest on the whole of the subject at once; the light necessarily falling on the prominent parts, would have a brilliancy injurious to the effects of the other parts, on which it did not fall in the same manner. The colours used in enamelling are all calxes of metals, mixed and melted with certain proportions of a vitreous substance which, at the instant of their fusion, discover their tints and fix them on the metallic plate. This melted glass or enamel produces the same effect that oils gums or glues produce in other processes of painting. It unites the different particles of the colouring materials, makes them adhere to the surface of the enamel, and incorporates them with itself: when properly managed it gives the colours a degree of brilliancy and polish not to be obtained in any other way. Many colours are not requisite in this kind of painting; the following are sufficient to produce all sorts of tints. It was formerly thought necessary to have colours of different degrees of hardness: the hardest to be used in the beginning of the work, and the softer colours in finishing, as requiring a moderate heat: these precautions are now however disregarded. Without entering at present into any detail of the manner of procuring the various colours, it may be noticed that from gold are formed the scarlets, purples, pinks and violets; from silver and antimony the yellows; from copper the greens; from cobalt the blues; from iron the deep reds, blacks and browns; from tin the whites. These colours are the basis, or rather the materials of which those used in enamel painting are composed, viz. the following:

Deep purple. Rose purple. Violet purple. Deep and warm yellow. Brilliant and light yellow. Straw-coloured yellow. Blue. Green. Black. Dark brown; and white, for the last touches.

Three different purples are mentioned, because the deepest is used for the strongest touches, and consequently with a thick body of colour,

producing a warm tone; but if, on the contrary, it be used thin and faint, the tint will be too much of a violet hue, and not sufficiently near to a pink. The second, or rose purple, has a contrary effect; that is to say, if it be used too thick, it loses its force, but when laid on faintly, it produces a most brilliant rose colour. It is therefore proper, on procuring these colours, to try the deep purple by strong touches, and the rose purple by a light wash, to discover whether they correspond to the tints you wish to produce. The violet purple, if it may be so called, is more brilliant when you buy it ready prepared, than when you make it up with a mixture of blue and purple. The same thing happens with the yellows, which when used in a faint state, do not give a tint so strong and brilliant as when applied thick, at least this is rarely the case. The blue is a very cold colour, and becomes deeper every time it passes through the fire; it is therefore to be used with caution, and only on the carnations: it may be made warmer, by mixing it with a little yellow. The greens, most of which are procured from copper, are extremely brilliant, but do not stand: they are used in the draperies, back-grounds, &c. and are only to be applied when the picture is to pass the last time through the fire. Such greens as are necessary in the carnations are composed of blue and yellow. As it is difficult to procure blacks that will stand, it is best to sketch such parts as require it with mixtures of dark yellow, blue, deep or violet purple; in the last touches you may use black alone. If browns that will stand are not to be obtained, they may be composed of those colours just mentioned to form a black, only adding a greater proportion of deep yellow and deep purple.

The colours employed in enamelling are to be reduced to the finest powder, and afterwards ground down with water, with all possible care, each upon separate glasses. They should be ground only in small quantities at a time, because the extreme separation of their component particles greatly aids the required changes, when in a state of fusion, and improves their brilliancy and fine polish. They are afterwards left to dry upon a glass covered with paper, to preserve them from dust, and then, like the colours used in miniature painting, ought to be put into small phials, well stopped. When the colours have been thus well ground with water, some essential oil of lavender must be procured, and thickened to prevent it from evaporating too quickly when exposed to the fire. The way to thicken it is to pour a quantity into a plate, a quarter of an inch deep, cover it with a piece of gauze, and expose it to the heat of the sun until it begin to flow, and seem to have the fluidity of olive oil, which happens in a longer or shorter time, according to the season of the year. This oil is then put up in a clean phial, and the operation is repeated until a sufficient quantity be procured. Should it, however, become too thick, or *fat*, as it is called, it must be mixed with a little oil that has not gone through this process. Oil of lilies may be also employed for the same purpose, and requires no preparation of this sort. It has another advantage, that it does not evaporate in the open air, and thereby leaves the artist the power of judging of the force of his tints, and of the harmony of his work: but when this oil has been employed, the painting ought, previously to its being placed in the furnace, to be exposed to the heat of a charcoal fire, gradually increased, until the oil be entirely evaporated. If the work were placed in the furnace immediately after it is painted, the colours would bubble and

spread in all directions, and the picture be entirely spoiled. This, however, does not happen with the oil of lavender, for it evaporates in the ordinary heat of the air; but it sometimes occurs that when the upper part of the painting is finished, and the work is resumed next day, the colours have been imbibed and dried up, so that it demands the greatest experience and practice to regain the same strength of tones, in the other parts of the work. As it is only after the plate has been passed through the fire that any judgment can be formed respecting the effects, you may, therefore, in the beginning, use the oil of lavender, and in harmonizing darkening or otherwise changing the lights, employ the oil of lilies. The colours are mixed with the oil, on a piece of glass or agate, until they feel as soft as oil under the muller; they are then arranged in small heaps, on another piece of even glass, and placed in a box, which must be only half opened when necessary, that no dust may enter. Under this piece of glass is laid some white paper, that the different colours may be the more visible. To prevent the colours from being soiled, and one from mixing with another, you must be careful, after using any of them, to wipe the glass with a piece of fine linen rag, dipped in spirits of wine. The simple colours ought to be placed on the upper part of the pallet, and the mixed colours on the lower part; observing, that the pallet should be renewed every morning, as the colours are never so good when the oil has evaporated and has lost part of its fluidity. When the pallet is thus in order, you must with an ivory knife take, from among the principal colours, those necessary to form the tints, in the manner hereafter mentioned. Having wiped, with a piece of fine linen and spirits of wine, the enamelled plate on which you mean to paint, then with a black-lead pencil draw very faintly the outline of the subject, and pass a linen cloth lightly over the whole, to remove any of the grosser parts of the lead remaining on the plate. If this be not done, when the work is exposed to the fire, the small particles of the pencil, broken off in the shape of a fine powder, will rise up in bubbles, and remain tinged with the colours to be afterwards laid on. When this operation is over, a second outline is drawn, more strongly expressed than the first, with deep purple. This second outline should be as correct as possible, because when it has passed through the fire it is very difficult to efface the most trifling touch. It is of use here to have a piece of hard wood, pointed like a pencil, with which the outline may be corrected, by moving the colour more to the right or the left, as may be necessary. When the outline is done to your satisfaction, and every thing is drawn in its proper situation, then the work must for the first time be exposed to the fire. If you now perceive that any air-bubbles have arisen, or that any part of the colour remains rough, you must take a small piece of oil-stone, or a steel point well steeped, and rub the place, but not going very deep, till the white ground appear; after which the plate is put into the fire, to repolish the part that has been rubbed, and fit it to be repainted. When this second outline is finished, and the plate has been again wiped with a cloth dipped in spirits of wine, begin to paint the strongest shadows with a mixture of dark purple dark yellow and a little blue; by means of these three colours you produce the same warm tone with what is drawn from burnt terra di sienna and indigo. The method of applying the colours in enamel is the same as in miniature painting on ivory, with this difference only, that as oil takes more time to dry than water, the

enameller has more time to work his colours, after they are applied to the plate. When you have placed and softened one touch you must leave it and wait till it is again passed through the fire; otherwise the too great quantity of oil, confined under the second coat of colour, will, in the moment of fusion, make the upper ones bubble, and prevent them from polishing. It is to be observed, that all the colours when they come out of the fire ought to have nearly the same degree of polish.

Painting on Glass. Under this title, different modes of painting on glass are comprehended. The most ancient was very simple, being in fact only a sort of mosaic, executed with pieces of glass stained with various colours; then larger pieces of stained glass were used, and the features and shades applied to them, with other coloured substances; lastly the colours were incorporated in the materials of the glass itself, by the operation of fire. This idea is said to have been first suggested by a French painter at Rome; but Albert Durer, and Lucas of Leyden produced the earliest specimens of the art, approaching to perfection. The colours used in painting or staining glass, are very different from those employed in working with oil or water colours. Of these the following are some examples.—Blacks are obtained by a mixture of scales of iron, scales of copper, and jet, all in equal quantities, reduced to a fine powder. For blues, take of powdered blue one pound, salt of nitre half a pound, well mixed together.—For carnation, take of red chalk eight ounces, iron scales and litharge of silver each two ounces, gum arabic half an ounce; mingle these ingredients in water, and grind them together, leaving them to settle for a fortnight in the vessel.—For green, take red lead one pound, copper scales one pound, flint five pounds; put them, with some nitre, in a crucible, in a very strong fire, and after they are melted and cold, grind the mass to a fine powder.—For gold colour, take silver one ounce, antimony half an ounce, melt them down, and grind the mass, adding to the powder fifteen ounces of yellow ochre, and then reducing the whole to a fine powder, by grinding them in water.—For purple, take red lead one pound, white lead one pound, white flint five pounds, brown ochre one pound, and one-third of a pound of sal nitre; calcine and melt them down together, and reduce them to powder.—For red, take jet four ounces, litharge of silver two ounces, red chalk one ounce, powder and mix them.—For white, take jet two parts, and white flint ground fine one part, and mix them together.—For yellow, take Spanish brown ten parts, silver leaf one part, antimony half a part, and calcine them together in a crucible. In the windows of ancient churches are frequently seen the most beautiful and lively colours, far exceeding those employed by modern artists. But this difference is occasioned not so much by ignorance of the methods pursued in those times, as by the high price of the materials requisite, which would not be defrayed by the little demand there is in the public for works of this nature. Formerly the colour was infused into the substance of the glass itself, or it was only applied on one side, penetrating but a short way into the glass; this last could be done only with certain colours, for others, yellow for instance, were always found to pervade the whole substance, or at least to go very deep.

In the art of painting on glass, as practised, or rather as it ought to be practised, the first thing to be done is to draw and colour the

subject on paper; then the artist chooses such pieces of glass as are clear and smooth, to receive the several parts, and distributes the drawing to suit the pieces of glass, making the contours or bounding lines of the figures fall in the joinings of the several pieces, that the carnations or other bright and transparent parts of the work may not be covered by the lead joinings of the glass. When this distribution is made, each piece of the glass is marked corresponding to that part of the paper-sketch to which it belongs; thus the design is transferred from the paper to the glass, following all the lines and strokes as they appear through the glass, with the point of a pencil. When these strokes are dry, which may be in a couple of days, the work now consisting only of black and white, is lightly washed over with gum arabic, urine, and black; and this is repeated several times, according to the deepness of the shades, taking care not to apply a new coat of wash until the former be quite dry. The lights are improved, by rubbing off, with a wooden point, the colour in the proper places. The other colours are applied with gum arabic, much in the same way as in miniature-painting; observing always that the yellows are to be managed with great precaution, for they are very apt to blend and incorporate with the other colours, and thereby spoil the whole work: they are also the only colours that penetrate through the substance of the glass, when exposed to the action of the fire; all others, particularly the blues, remaining on the surface, or only penetrating a short way within it. When the painting is performed in this manner, the glasses are carried to the oven or furnace, to be annealed or baked. This furnace is made of brick, from twenty-four to thirty inches square. An aperture is made six inches from the bottom, to receive the fuel; a grate is placed across the furnace like a flooring, above which is another aperture to admit the pieces of coloured glass. This grate supports an earthen pan, in which the pieces are laid in the following manner: in the bottom of the pan are placed three strata or layers of pulverised quick-lime, separated by layers of old broken glass, to preserve the painted pieces from receiving too much heat, when they are laid horizontally on the uppermost stratum of quick-lime. Each stratum of the painted glass is separated from the one above it by a layer of the same powdered quick-lime, and the uppermost stratum is covered with lime in the same way. The whole furnace is then covered with a broad flat tile, and closely stopped or luted all round, leaving only a few small holes to serve for chimnies. The fire for the first two hours should be moderate, but increased as the annealing or baking goes on, for ten or twelve hours more, when the process will be finished. At the conclusion of the whole, the fire, which at first is made of charcoal, is made up with live wood, that the flame may surround and cover the pan of glass, &c. and even come out at the little chimney holes. Trials of the state of the glass are made by taking out pieces placed in the pan for this purpose, at the small aperture in the furnace; and when the annealing or coction is thought to be sufficently advanced, the fire is extinguished as speedily as possible, to prevent the glasses from being broken, and the colours from being burnt, dissipated, or changed.

It may here be proper to mention the result of a set of experiments instituted by the celebrated French chemist *M. Guyton de Morveau*, to discover some substitute for the *white* colours generally used, which being extracted in different ways from lead, all partake more or less of the

deleterious qualities of that metal; for the various preparations hitherto made of lead, have naturally enough been directed to the obtaining of a purer and more lasting white colour, rather than to a due consideration of the health of those who are to use the colours. The experiments in question were conducted with an eye to the two following conditions, essential to the production of good colours. The first is, that the colours are easily diluted, and take a good body with oils or mucilages, a circumstance depending greatly on the affinity between these substances. When the affinity is very strong, a dissolution ensues, the colour is extinguished, and the compound becomes transparent; and when the affinity is weak, the colour remains only suspended in the fluid, and appears on the canvass like loose sand. The second is, that the colouring body be not of a volatile nature, and that it be not connected with a substance of a weak consistency, by which the compound would be liable to spontaneous decay: hence it is impossible to employ the greater part of vegetable colours, whose finer parts cannot be united with other substances more solid. Experiments were made with the various sorts of earth, whether pure or metallic, and with sundry earthy compositions which appear sufficiently white for the purposes of painting; but all these substances refuse to unite with oils or mucilages, and their white colour is extinguished when they are ground with such liquids. The blue of ultramarine, extracted from the blue jasper, commonly called lapis lazuli, seemed to warrant the idea that the opaque half vitrified compositions of the nature of jasper might be rendered useful in painting. The experiments, however, furnished the same results as those with the pure earths; since it is not the substance peculiar to the jasper which constitutes ultramarine blue, but the metallic substance which accidentally colours the particular species of jasper. In this way art should, in its imitations of nature, endeavour to give a permanent base to some colour already formed, to fix it without alteration, and to increase, perhaps, its splendor and intensity, but not to produce a new colour.

Of the metallic substances there are nine which yield white calces, (oxydes) viz. silver, mercury, lead, tin, antimony, bismuth, zinc, arsenic, manganese; but the calces of the first six metals constantly turn either black or yellowish. On the other hand, *zinc* furnishes, by all the processes of calcination and precipitation, a white calx, when it is pure and separated from iron, otherwise the preparation of vitriol of zinc will become yellow when exposed to the air. In all the precipitations of zinc, an earthy substance of different shades of white was produced, which, when dried and prepared, mixed readily with oil and mucilage, without losing its colour, and undergoing no sensible change when exposed to phlogistic vapours. In consequence of discovering these valuable properties, experiments were repeated to ascertain the most certain and most economical mode of preparation of the zinc, and the result was, that the calcination of this metal alone gave the purest, the whitest, and the least changeable calx; and that to obtain the best colour, it was sufficient to separate, by means of water, the burned from the unburned parts, grinding the former with some earth of alum or chalk, to give the pigment a proper body. The white obtained in this way from zinc, may become of the greatest use to painters, as it may be procured at a moderate expence, and is applicable to many purposes. It might even be made in such quantities as to supply the place of ceruse or white lead, in

all parts of painting, even in interior house-painting, where it ought certainly to be preferred; not so much on account of its brilliancy, as for the safety of the workmen, and even of the inhabitants of houses ornamented with white painting; notwithstanding that this white of zinc may perhaps never be procured so cheap as white lead. Late experiments have succeeded in giving to the white of zinc a greater body than at first, by which its slowness in drying in oil has been considerably remedied; but this defect may be removed by adding to the colour a little vitriol of zinc, or white copperas slightly calcined, which combines better with the white of zinc than with any other colour. This mixture may be made on the pallet, which will cause no alteration in the original colour, and even in a small proportion be productive of a great effect.

Economical painting. This branch of painting is very extensive, comprehending the mechanical processes for preserving and ornamenting walls of houses, furniture, &c. Of the utensils, brushes and pencils of all sizes are requisite: the brushes ought to be straight, round, and smooth; they should before using be washed some time in warm water, that the wood of the handle may swell and retain the hairs, which would otherwise be apt to fall off, and adhere to the work. The brushes are commonly made of boar's bristles, or of a mixture of bristles and hair; the pencils are made of badger's hair, or other fine hair, and fixed in quills of different sizes. The vessels used to hold the various paints should all be well varnished, to prevent their drying quickly. When the colours are ground in water, they should be diluted in size made from parchment; and when diluted with spirits of wine, no more must be used than what will be necessary for the immediate occasion, as colours prepared in this way dry rapidly. Colours ground in oil are also diluted with pure oil, or oil mixed with essence of turpentine, or even with pure turpentine, which makes them easy to work; but when varnish is added, only what is requisite for the moment should be prepared, as it must be immediately applied. The addition of varnish gives the colours great brilliancy, and dries speedily, but more art is necessary in using them. This part of painting is divided into water and oil colours, with or without the admixture of any varnish. Painting in water colours is to do it with those which are ground down in water, and then diluted in size; it is also divided into common and varnished painting. Before any of these are applied, it is necessary to take care that no grease remain on the substance to be painted. The several layers or coats, especially the first, should be laid on warm, but not so as to affect the wood; and the last coat, given immediately before the varnish, is the only one which should be applied cold. Whatever colour is to be laid, a white ground is the most proper, as it unites well with all other colours, which always partake a little of the nature of the ground. Works requiring no particular care or preparation, such as stair-cases, cielings, and the like, are commonly done with water-colours, or earths infused in water, and applied with size; for a common white Spanish whitening is employed, pounded and steeped in water until it be dissolved; then infuse a due quantity of charcoal black for the same time, and mix it with the white until you have got the tint desired. These are next mixed together with good size, sufficiently thick and warm, and laid on in as many coats as may be requisite. If the walls to be painted are new built, a greater quantity of size is necessary than when they are

old. In general it is to be observed, that all colours should be ground, and mixed to the proper degree of tint in water only, and the size added afterwards, to give them consistency. A very beautiful white colour is given to walls by the following preparation. Take a quantity of the very best lime, and pass it through some fine linen into a large tub, furnished with a spigot at the height of the surface of the lime: fill the tub with clean soft water, then beat up the mixture with a piece of wood, and let it settle for twenty-four hours. The spigot is then opened, and the water drawn off; in the same way fresh water is added, and drawn off repeatedly, until the lime has acquired a very brilliant whiteness. When the last water is carried off, the lime will be found in the consistency of paste; but, before it be used, a small quantity of Prussian blue, or indigo, must be added, to relieve the brightness of the white, and a little turpentine to improve its brilliancy. The proper size for using with this composition is made of glove-leather and alum, to be applied with a strong brush in five or six layers on new plaster. The wall is next to be rubbed strongly, after the painting is dry, with a stiff brush, which will give it a lustre resembling stucco or marble. Cielings and roofs of rooms when new, may be done with good whitening, mixed with a little charcoal black, to prevent the white from turning redish. Infuse them separately in water, and mix the whole with half water and half glove-leather size. If the roof has been whitened before, the old colour must be entirely scraped off, and two or three layers of lime applied for a ground, and the new colour laid on in two or three coats. But however expeditious and beautiful the method of using water-colours may be, yet, by the introduction of varnish, several advantages are produced, such as that the colours are not liable to fade, they reflect the light, give no offensive smell, but permit the chamber or house to be inhabited soon after the operation, and the wood is preserved from insects and moisture.

To make a fine varnish, or water colour, sundry operations are necessary, namely, to size the wood, to prepare the white, to soften and rub the work, to clean the mouldings and carved parts, to paint, to size, and varnish the whole. The wood is sized in this manner: take three heads of garlick, and a handful of leaves of wormwood, boil them in three pints of water down to one, pass the juice through a linen cloth, and mix it with a pint of parchment size, add half a handful of salt, and half a pint of vinegar, and boil the whole over the fire. With this boiling liquor size the wood, allowing it to penetrate into the carved and smooth places, but taking care to take it as clean off the work as possible, or at least to leave it at no place thicker than at another. The first operation fills up the pores of the wood, and prevents the materials afterwards from collecting in a body, which would cause the other layers to fall off in scales. The next thing to be done is, in a pint of strong parchment glue or size, diluted with four pints of warm water, put two handfuls of fine whitening, and infuse the whole for half an hour; stir this well, and give a single coat of it very warm, but not boiling, laid on smooth and equal, dashing repeated strokes into the hollows and carved parts. To prepare the white colour, take some strong parchment size, and sprinkle lightly over it with the hand, the fine whitening to the thickness of half an inch: allow this to soak in, for half an hour, near the fire, to keep the size warm, and then stir it with the brush till the lumps are broken down, and the composition be properly mixed. With this white lay on

as many coats as the nature of the work requires, observing that the layers should be all as nearly as possible of the same colour and consistency. The last coat, however, ought to be clearer and thinner than the others, and this is produced by adding a little water; it is applied more lightly, taking care with small brushes to cover all the difficult places of the carvings and mouldings. It is also necessary, between the drying of the different layers, to fill up all the defects with white mastich and size. What is called softening the work, is to give it, when whitened, a smooth and equal surface, and to rub it over with pumice. When the wood is dry, take small pieces of wood and of pumice shaped in different ways, for working on the pannels and mouldings. Then take cold water, (for any heat would destroy this sort of work) moisten the wall with a brush, or at least so much of it as can be worked at once, lest the water should penetrate too much, and spoil what has been formerly done: then rub and smooth it with the pieces of wood and pumice; next wash it with a brush as the polishing goes on, and rub it over with a piece of new linen, which will give a fine lustre to the whole.

House painting with oil colours. By means of oil, all colours are longer preserved, and not drying so speedily as water colours, they give the artist more time to smooth, finish, and retouch his work: the colours also being more marked, and mixing better together, give more distinguishable tints, and more vivid and agreeable gradations; the colouring is thus rendered more sweet and delicate. Paintings are executed either with simple oil, or with oil and varnish. When bright colours, such as white and light grey, are ground and diluted in oil, that of walnuts is the best, but for dark colours, linseed oil is to be preferred. They must be laid on cold, unless it be on new or moist plaster, which requires them to be boiling warm. You should be very attentive to stir the colour often, to prevent it from subsiding, and leaving the oil on the surface; but if, notwithstanding care, the colour should be thick at the bottom, a little more oil must be added from time to time. In general, all works to be painted in oil ought to receive a coat or two of white lead ground and diluted in oil. Where the painting is to be exposed to the air, as in doors, windows, and other similar works where varnishing is not applied, the layers of paint should be made with pure walnut oil: in work within doors, or when the painting is to be varnished, the first layer ought to be ground and diluted in oil. When there are many knots in the wood, as is the case with fir, which do not easily take the colour, it is necessary when painting with pure oil, to apply a little oil mixed with litharge, on the knots. As there are several colours which are difficult to dry when ground in oil, it becomes necessary to introduce other substances of a drying quality, by which the effect is produced. Of these there are various sorts; one composition frequently used is prepared in this manner:—Take half an ounce of litharge, as much calcined white lead, as much powdered umbre, and the same quantity of talc. These ingredients are boiled for two hours on a slow equal fire, with one pound of linseed oil, and kept stirring the whole time: this must be carefully skimmed and clarified, and the older it grows, it is the better for use. Doors and windows to be painted in pure oil colours, have first a coating of white lead ground in walnut oil, with a little of the above drying composition, or *siccative*; then another coat of the same, to which, if a greyish colour be wanted, add a little Prussian blue and charcoal black, also ground in walnut oil. The last

coats should have less oil in them than the first, and the colour will be more beautiful, and less apt to blister in the sun. Walls that are to be painted in this way ought to be very dry, and receive two or three layers of hot linseed oil, to harden the plaster, then two layers of ochre or white lead, ground in the same oil; and when these are dry, the wall is ready to be painted. To paint tiles of a slate colour, grind separately white lead and German black in linseed oil; mix them together in the proportion of the desired colour, and dilute them in the same oil; then give the first coat very thin, to prime the tiles, and make the following coats thicker, to give a body to the work. Arbours and all sorts of garden work require a coat of white lead ground in walnut oil, and diluted in the same, with the addition of a little litharge; then two layers of green, consisting of one pound of verdigris to two pounds of white lead, ground up in walnut oil. This green is also of great use in the country for doors, window shutters, seats, rails, whether of iron or wood, and in general for all works exposed to the weather. Statues, vases, and all other stone ornaments, either within doors or without, ought first to be well cleaned, then have a couple of coats of white lead ground in oil of pinks, and finished by an additional coat of the same. In painting on walls not exposed to the air, or on new plaster, the best way is to give one or two coats of boiling linseed oil, applying it till the walls are quite soaked; then give a coat of white ceruse, ground in walnut oil; and lastly, two other layers of ceruse in oil of walnuts. In this way walls are painted white; but any other colours may be applied by employing them in a similar manner. To paint chairs, benches, stone or plaster, give a layer of white ceruse ground in walnut oil, and diluted in the same, having in it a little litharge to make it dry: then apply a layer of the tint you have chosen, and afterwards one or two more, varnishing the whole with spirit of wine varnish. A steel colour is produced by ceruse, Prussian blue, fine lac and verdigris, mixed in such proportions as to give the colour required. Balustrades and railings are done with lamp black and varnish of vermilion in two coats, and finished with spirits of wine varnish.

Since the discovery of oil-painting, and the knowledge that wood is preserved by it, and especially since the discovery of a varnish without smell, and which even takes away the smell of oil, the painting of apartments in oil has been justly preferred to any other method. Oil stops the pores of the wood, and although it does not altogether resist the impression of moisture, yet the effect is so little perceptible, that it is to be recommended as the best way known to preserve wood. To preserve wainscoting in the most effectual manner, it is proper to paint the wall behind it with two or three coats of common red, ground and diluted in linseed oil. The wainscot itself is painted first with a coat of white lead ground, and diluted in walnut oil; when this is dry, two other coats of the same are to be applied. Two or three days afterwards, when the colour is dry, apply a coat or two of the white varnish without smell, to drown that of the colours. The first coats of this work may also be done in water colours, and the varnish applied as before. When the pores of the wood are well stopped by the white preparation, a layer of white lead, ground and diluted in walnut oil, may be applied, which will be sufficient, the wood being previously primed, and then the intended colour and varnish.

Painting in varnish. This is to employ colours ground and diluted in

varnish, either in spirits of wine or oil, on all sorts of materials. In this manner, wainscoting, furniture, carriages, &c. are painted. To paint apartments in this way, give two layers of fine whitening diluted in a strong size, and boiling hot: then fill up any holes or unevenness of the wood with mastich in water, and when dry smooth the layers with a pumice. When the wood is thus made even, suppose you were to paint a grey colour, take one pound of white ceruse, one drachm of Prussian blue, or of charcoal or ivory black; put the whole into a piece of leather, so tied that the colours cannot escape, and shake them till they are sufficiently mixed; then put two ounces of colour into a quartern of varnish, and when well mixed, apply two coats over the white ground. This being dry, put one ounce of colour into the same quantity of varnish, and give another coat. Again, with half an ounce of colour in the same quantity of varnish, apply a third coat. As each of these dries, it must be carefully rubbed with a piece of coarse new cloth, but so as not to injure the surface of the colour. These three layers may be applied in one day, and if a still greater lustre is wanted, a fourth may be added in the same way. In this manner any other colour may be applied; and it is the only one by which orpiment can be employed so as to preserve all its beauty, although retaining some of its defects. Another way of executing this kind of work, is to apply the colours and the varnish without previously using the size and the white ground. This method is very expeditious, but it has the defect of not being susceptible of the high polish and brilliancy of the former method.

CHAP. VI.

OF ENGRAVING; AND THE USE OF THE DRY NEEDLE.

There are several species of engraving which may principally be divided into engraving on metals, on wood, on stones, and on glass. But of every kind of engraving there is none to which the polite arts are more indebted, or which have afforded a greater benefit to mankind, than that of engraving on copper-plates.

This may be defined, the making of concave lines on a smooth surface of copper, corresponding to some delineated figure or design, either by cutting with a tool, or by corrosion with some dissolvent menstruum; so as to render the plate capable, when charged with any coloured fluid, of imparting, by compression, an exact representation of the figure or design to paper, parchment, or any proper substance.

Engraving merits a very distinguished place among the fine arts. It is not only an invention of great utility to mankind, but affords to the mind a particular pleasure in contemplating the perfection to which it is brought, particularly when we consider the difficulty attending its execution. By means of this art the cabinets of the curious are adorned with the portraits of the greatest characters of all ages and nations; the

most remarkable occurrences of their lives are preserved, and transmitted to posterity with all their appending circumstances, and that in a more striking manner than could be performed by the pen of the poet or the historian. The great and most important events of ancient history are still perpetuated and presented to our view. We are transported to ancient scenes, we view, as if actually present, the devastation which reigned in ancient fields of slaughter; we enter into the contest, and for a moment forget we are beings of a posterior generation. We form a more adequate idea of the fables of the earlier part of our race, by seeing pourtrayed the nereids, deities, nymphs, &c. who influenced the actions and regulated the conduct of mankind, for upwards of half the age of the world. It is by this art that painting itself is rendered so generally useful to mankind, as by it the works of the greatest masters are multiplied beyond number; that the admirers of the fine arts are able, in every part of the globe, to enjoy those beauties from which their distant situations seem to have for ever debarred them; and that persons of moderate fortune have hereby the means of being possessed of all the spirit, and all the poetry, that are contained in those miracles of art, which seem to have been reserved for the temples of Italy, or the cabinets of princes. When we reflect, moreover, that the engraver, besides the beauties of poetic composition, and the artful ordinance of design, is to express, merely by the means of light and shade, all the various tints of colours and *chiaro oscuro*; to give a relief to each figure, and truth to each object; that he is now to paint a sky, serene and bright, and then loaded with dark clouds; now the pure tranquil stream, and then the foaming raging sea; that he is here to express the *character* of the man, strongly marked in his countenance, and there the minutest ornament of his dress: in a word, that he is to represent all, even the most difficult objects in nature, we cannot sufficiently admire the vast improvements in this art, and the high finishing observed in some of its most beautiful productions.

This art had its origin, as it now exists, at no earlier a period than about the middle of the fifteenth century. The ancients practised engraving on precious stones and crystals with very good success; some remains of their ingenuity in this way are yet extant, and are equal to any productions of modern times: but the art of engraving on copper and wood was not known till long after the invention of painting in oil.

The different kinds of engraving on copper are the following:

1. Engraving in strokes with a point, the copper-plate being covered with a ground, and the strokes afterwards corroded with aqua-fortis: this is called etching.

2. In strokes with the graver alone, unassisted by aqua-fortis. In this case the design is traced with the sharp tool called dry point, upon the plate, and the strokes are cut in the copper by the graver. This is generally called engraving with the tool and dry point only.

3. In strokes, but which are first etched with aqua-fortis, and then finished with the graver: by which the two former methods are united. This mode is the most universally practised, and has also the best effect.

4. In dots, without strokes, which are performed with the point upon the wax or ground, and then bitten in with aqua-fortis, as in etching; but they are afterwards harmonised and softened with the graver, by making several small additional dots between them. Sometimes this

mode of engraving is effected with the graver only, unassisted by the point, which is very often the case in the flesh and the finer parts of portraits.

5. In dots, which are first etched as the foregoing, but afterwards harmonised with the dry point, performed by a little hammer instead of the graver. This operation is now nearly exploded.

6. In mezzotinto, which is performed by covering the plate with a strong dark ground, or deep shade, by means of a toothed tool, and corroding the dots with aqua-fortis. The parts which are to be light are then rendered more or less smooth by the scraper, according to the degrees of light they are to represent.

7. In aquatinta, which is a newly-invented method of engraving, but has suddenly attained a degree of perfection seldom the lot of recent discoveries: the outline is first etched, and the plate afterwards corroded, but in a different manner from either etching or mezzotinto, as will be explained hereafter.

The first accounts we meet with of engraving on copper is from some German annals, about the year 1450. The earliest copper-plate extant is dated 1461, which, notwithstanding its rudeness and imperfections, sufficiently evinces that the engraver was no stranger to the use of his instruments: and the copper-plate printer far from being unpractised in his art. From several other engravings of the same master, we may discover that the printing of these plates had become a mechanical profession: the impressions are so clearly taken in every part, that it is a doubt whether they could be exceeded by the copper-plate printers of the present day, with all the conveniences they now possess, and the additional knowledge they must necessarily have acquired in the course of between three and four centuries. Hence, it may be fairly concluded, that if they were not the first specimens of the engraver's workmanship, they were much less the first efforts of the copper-plate printer's ability. It is likewise to be observed, that Martin Schoen, who is said, with great appearance of truth, to have worked from 1460 to 1486, was, apparently, the scholar of Stoltzhirs; for he followed his style of engraving, and copied from him a set of prints representing the Passion of our Saviour: now, allowing Stoltzhirs to have preceded his disciple only ten years, this carries the æra of the art back to 1450, as was said above. There is no ground to suppose that it was known to the Italians till at least ten years afterwards. The earliest prints that are known to be their's, are a set of the seven planets, and an almanack, by way of frontispiece; on which are directions for finding Easter, from the year 1465 to 1517 inclusive: and we may be well assured that the engravings were not antedated, for the almanack, of course, became less and less valuable every year. In all probability, therefore, these prints must have been executed in the year 1464, which is only four years later than the Italians themselves lay any claim to. The three earliest Italian engravers, are Finiguerra, Boticelli, and Baldini. If we are to refer these prints to any of the three, we shall naturally conclude them to be the work of Finiguerra or Baldini; for they are not equal neither in drawing nor composition to those ascribed to Boticelli, which we know, at least, were designed by him; and as Baldini is expressly said to have worked from the designs of Boticelli, it will appear most probable that they belong to Finiguerra.

With respect to the invention of etching we must speak with less cer-

tainty. Albert Durer has left us an early specimen of this art, in his piece known by the name of the Cannon, dated 1513: he has also bequeathed us another etching, dated 1524, representing Moses receiving the tables of the Law. Parmegiano soon after practised it in Italy. In his works we discover the hand of a great man, labouring under innumerable difficulties, and working, as it were, upon a system of his own invention. We cannot help admiring his efforts, though he failed in producing the forms he wished to express: on examining the mechanical part of the execution we may plainly perceive that the subject was novel to him, and that he had had no instructions or directions: he died in the year 1540.

That species of engraving which unites etching with the use of the graver, was, no doubt, adopted very early; that is, immediately upon the invention of etching: but G. Audran was the first who carried it to perfection. The Italians, however, have not entirely excluded themselves from their share of honour in this branch of the arts. Agostino Demusis, commonly called *Augustine of Venice,* a pupil of Marc Antonio, used it in several of his earliest works, but confined it to the flesh, as appears in the print of an old man seated on a bank, with a cottage in the back ground, without any date. Augustine flourished from 1509 to 1536. We have also another print of this nature, by Giulio Campagnola, of a single figure, standing and looking upwards, with a cup in his hand, and said to be engraved about the year 1516; the back-ground is executed with round dots, made apparently with a dry point; the figure is outlined with a stroke deeply engraved, and finished with dots, in a manner greatly resembling those prints which De Marteau engraved at Paris, in imitation of red chalk. The hair and beard are expressed by strokes. Stephen De Laulne, a native of Germany, followed the steps of Campagnola; executing many of his slight works in dots only. This kind of engraving was greatly improved about the middle of the seventeenth century, by John Boulanger, a French artist, and his contemporary, Nicholas Plattenberg; but it is only within the last fifty or sixty years that it has been deemed an object worthy of general imitation. John Lutma executed his works of this kind, with a hammer and a small punch or chissel, and was the first who practised that mode, which was afterwards, for some time, generally followed.

Engraving in mezzotinto is a later discovery than the foregoing: invented by Prince Rupert about the middle of the seventeenth century, though it is generally asserted that he had the secrect from another.

Engraving in aquatinta is the most modern of the whole, and does great honour to the improved state of the arts of the present age, whether we consider it with regard to the beauty of its effect, or the ingenuity displayed in the execution of the work throughout. It partakes of the excellence of all modern discoveries, namely, arriving to a considerable state of perfection, even while in the hands of the inventors.

Engraving in strokes, or hatches, with the tool, is undoubtedly the most ancient kind of engraving, and is still retained for many very useful and valuable purposes. For though etching be performed with a great deal more ease and expedition, and has several other advantages attending it; yet the strokes, or lines, are by no means so regular and exact as those wrought by the graver: for this reason, where great

precision is required, engraving with the tool is preferred; as, in the execution of portraits, where the most minute parts must be expressed according to the original subject, without the least deviation, or varying the effect, either by that masterly negligence and simplicity in some parts, or those bold sallies of the imagination and hand in other parts, which give such spirit and force to historical painting.

The principal instruments used in engraving with the tool, are gravers, scrapers, a burnisher, points or needles, compasses, an oil stone, and a cushion or sand-bag, for bearing the plate. Gravers are of two sorts, the square and the lozenge: several of each kind should be provided. The square graver is used for cutting broad and deep strokes, and the lozenge for the more fine and delicate ones. They should be about five inches and a half in length, including the handle. The scraper is used principally in scraping down the shades in mezzotinto; it is also serviceable in softening the parts, or clearing away the bur which arises in engraving. The burnisher is of service to polish the plate, and to take out any false strokes or scratches it may have received. It is about seven inches in length, and made of fine steel, well polished. The burnisher is formed at one end, and the scraper at the other, each about one inch and a quarter long from the point. The point, or, as it is generally called, the dry-point, has been lately introduced into engraving. It is a tool like an etching point, and which being drawn hard on the copper, cuts a fine stroke, and raises a bur; when the bur is scraped off, there remains a more soft and delicate stroke than could be effected by any other means. Compasses are very useful to take distances, proportions, strike circles, &c. They should be of brass, with steel points, well tempered. The oil-stone is used to whet the graver and point upon; it should be of the Turkey sort. The cushion is a bag of leather, filled with sand. Its use is to support the plate in such a manner that it may be turned every way with ease: it should be of the size that will best suit the plate it is intended to bear; it is of a round form; the most common size is about nine inches over, and three inches thick.

Directions for Practice.

The copper-plate being laid upon the cushion, the graver is to be held in the hand in such a manner, that the handle of the graver may rest in the hollow of the hand, and the fore-finger extended upon the back of the graver towards the point. The point of the graver being applied to the plate, it must be used in a proper direction for producing the figure of the lines intended; observing, in forming strait lines, to hold the plate steady on the cushion; and where they are to be finer, pressing more lightly; but using greater force where they are to be broader and deeper. In making circular and other curved lines, the hand and graver are to be held steadily, and the plate turned upon the cushion against the graver; though in some cases the plate and graver must be both moved, at the same time, one against the other: without a facility of moving your plate, as well as the graver, it will be impossible to make any circular or curved line with ease and neatness. When part of the work is done, it will be necessary to scrape off the bur which rises in the work; which must be done with

the scraper, passing it gently, in the most level direction, over the plate, which will take off the roughness; great care must be taken not to incline the edge of the scraper or tool used, in such a manner that it may take the least hold of the copper, which would produce false strokes or scratches in the work. When you wish to examine the part which is done, you may rub it with the oil-rubber, which is a roll of felt, dipped in oil; and which, by filling the strokes with black, will shew them, when the plate is wiped, to the best advantage. But it must be remembered, that too much oil rubbing injures very fine work; as does also too much scraping; the latter most particularly. The graver must always be carried as level as possible with the surface of the plate, for otherwise, or if the fingers slip between them, the line produced, whether curve or strait, will become deeper and deeper in the progress of its formation; which will prevent the student from acquiring the habit of making strokes at one cut, that will be fine at the ends and larger in the middle; and also renders it necessary to retouch the lines, to bring them to that state. It is very necessary, therefore, for all who attempt this art, to acquire the habit of forming strokes that may end as lightly as they began; and if it be necessary to widen the stroke, or render it deeper in any part, it is to be done by retouching it in that part with the square graver. Strong broad strokes are formed by making two or more parallel lines with the graver, and then breaking them into one. When the work is finished, if any scratches appear, any false strokes, or if it be necessary that any part should be obliterated, such parts may be rubbed out with the burnisher, and the part cleared with the scraper; afterwards it is to be lightly polished with the burnisher. The plate is lastly to be rounded off at the edges and corners, by using first a rough file, and afterwards a smoother one, and then polishing the edges with the burnisher.

In order to form a proper idea of this noble and elegant art of engraving in strokes, we may observe, once for all, that any line may be crossed by another line; or any number of lines by any other number of lines: but it is not every intersection or crossing that is graceful. For instance, if a number of parallel lines in an engraving be crossed by others running nearly in the same direction, they will form by their intersections a number of areas of a sharp and disagreeable lozenge shape, which is proper only in certain instances: and, if the first lines be crossed by others at right angles, the areas formed by their intersections will be so many squares; which always possess a certain hardness of appearance, and are proper only to some particular subjects: consequently, excellence in the art, and elegance of appearance, consist in neither of these forms solely, but in a medium between them, or a junction of these and other methods. For, in a well executed engraving we observe, in some places, some of the following modes, and, in the whole piece, all the subsequent varieties, and not, unfrequently, many others purely the invention of the engraver; 1. single lines, sometimes of considerable length; 2. lines crossed by others at a pleasant lozenge, not too acute; 3. lines crossed at right angles, where a kind of obscurity is wanted; 4. two courses of lines crossing at a lozenge, and intersected with a third in a lozenge course, but more soft and tender than either of the other two; 5. lines crossing each other at right angles, intersected by a third course

of lines at a lozenge which soften the squares, and render the work more elegant; 6. strong lines of a firm colour, at a considerable distance from each other, with a fine line between them; this is called *interlining*; 7. firm lines like the former, but crossing each other, and also interlined; 8. round dots, often made in the flesh, and where soft shades are required; 9. long dots made with the graver for the same purpose; 10. long dots crossing each other, or a kind of short broken lines; 11. lines of dots crossed by fine thin lines; 12. very fine thin lines made by the dry point in the light parts of the piece. Some of these methods, or similar ones introduced, according to the judgment of the engraver, produce that wonderful effect, richness, and character we so much admire in excellent prints, and which no other manner of engraving can boast of; it is also further enriched by a judicious mixture of etching, engraving, and the work of the dry-point.

From what has been said it is evident, that this art, with all its excellencies, consists only in the judicious mechanical management of the graver and dry-point: yet, of its numerous professors, very few attain superior merit: and it may be generally observed, that, of this happy few, not many excel in more than one branch. Though it does not require that fertility of genius the original artist should possess, it, nevertheless, is to be attained only by a dint of assiduity and practice. Few rules will suffice; but much depends on the patience and perseverance of the student. A few general leading principles to instruct the student in the method of producing certain well-known effects are all that he can expect from theory, the rest he must derive from his own practice and experience.

He who is well acquainted with design, and consequently the general principles of perspective and architecture, possesses the previous knowledge to the attempting this art; though it must be confessed there have been some very expert in the management of their instruments, who have also been greatly defective in those arts. It must be allowed, that a person unacquainted with perspective will be unable to express the proper degradations of strong and faint colours; and to throw back the figures and objects of his picture to their proper distance. And without a knowledge of architecture he will never understand the due proportions of the several orders, which the painter often entrusts to the discretion of the engraver. It is worthy of remark, also, to the engraver who would desire to excel, in order to preserve equality and union in his work, that he sketch out the principal objects of his piece before he undertake to finish them. With regard to the intersections of the lines of the graver, though (as before observed) they must not be crossed in too lozenge a direction, particularly in the representation of flesh, and in picturesque designs, yet we must except the case of clouds, tempests, waves of the sea, the skins of rough hairy animals, the leaves of trees, &c. where this method of crossing may be admitted. But, in avoiding the lozenge intersections, we must be careful of falling into the square, or right-angled crossings, which would have too much the appearance of the hardness of stone. The graver should be guided by the action of the figures; and the shape of the objects should also be considered; in what manner they advance towards, or recede from the eye of the observer. The risings, or cavities of the muscles should also be noticed, making the strokes wider and fainter in the lights, and closer and firmer in the shades. Thus the figures will appear whole

and finished: the hand should also be lightened in such a manner, that the outlines may be formed and terminated without being cut too hard. Though the strokes generally break off where the muscle begins, yet they ought always to have a certain connection with each other; so that the first stroke may often serve, by its return, to make the second, which will shew the freedom of the graver.

In the flesh, particularly the lighter parts, and middle tints, the effect may be produced by long pecks of the graver, rather than faint lines; but some prefer round dots for this purpose: others use dots a little lengthened by the graver: the best method, however, is to combine all those three ways together with judgment, for which no better direction can be given than carefully to examine the work in some excellent engraving. To produce the effect in the hair and beard, the principal grounds and chief shades should be sketched first, in a careless manner, with a few firm strokes, which are afterwards finished at leisure with finer and thinner strokes at the extremities.

In representing architecture, the work ought not to be rendered very black, except the subject be old ruinous buildings: because edifices being constructed generally of white marble, or stone, they reflect a light on all sides, and therefore do not produce very dark shades. Sculpture being generally formed of white stone, is governed by the same rule: and it must be observed in engraving from the work of the statuary, white points must not be put in the pupils of the eyes of figures, as in engravings after paintings; neither must the hair or beard have that freedom as in nature, where the locks appear flowing; because, in sculpture, no such appearance can take place.

The representation of different substances require not only different forms of lines and dots, but different modes of intersecting the lines, to produce a natural appearance. A great variety obtains both in the shades and lights of the different sorts of clothing; linen requires finer and closer lines than other sorts, and should also be executed with single strokes, or without interlining. Woollen-cloth should be engraved with only two strokes, which should generally be wide apart, in proportion to the coarseness of the cloth: but when the strokes are crossed, the second should be less than the first, and the third less than the second. Silk, sattin, and many other shining substances, produce flat and broken folds, and should, therefore, be engraved more hard, with straighter lines than others; and with one or two strokes, as their colours are more bright or brown; and the first strokes should also be interlined with smaller ones. Plush and velvet are also expressed in the same manner. Metals, and consequently ancient armour, are represented by clear single strokes interlined. In architecture, the strokes which form the rounding object should tend to the point of sight; in whole columns, perpendicular lines should be used as much as possible; and, if a cross stroke is introduced, it should be at right angles to the first stroke, and wider and thinner. In representing mountains, the strokes should be strait, in the lozenge manner, frequently discontinued, or broken, to represent sharp, craggy points: they should also be accompanied with long points, or dots: but rocks should be formed by cross strokes more square and even. All distant objects should have very faint and tender shadows, and be somewhat obscurely defined: the greater their distance is, the more indistinct they must appear. Calm still waters require strait strokes parallel to the horizon, inter-

lined with finer ones, omitting such parts, as, in consequence of gleams of light, exhibit the shining appearance of water; and the forms of objects reflected from the water are expressed by the same strokes retouched more strongly or faintly, as occasion may require, and even by some that are perpendicular. Agitated waters, the waves of the sea, &c. should be done with the first strokes following the figure of the waves, which should be interlined, and the cross stroke should be very lozenge. Cascades are represented by strokes following the direction of the water in its fall, which should also be interlined. In representing clouds, when they appear thick and agitated, the graver may turn in every direction, according to their form and agitation: but dark clouds, which require two strokes, have their strokes crossed more lozenge than the figures, the second strokes being wider than the first: flat clouds that are hardly visible, in a clear sky, are formed by strokes parallel to the horizon, but a little waving; if they be crossed with second strokes, these should be more or less lozenge; and when they approach the extremities, the hand should be lightened in such a manner that their ends may not form any outline. In representing a flat clear sky, strait parallel strokes must be formed, without the least winding. With regard to landscape it must be observed in general, that etching has a far better effect than engraving, on account of the freedom of the work, and the ease which appears in etchings above what is seen in engravings; therefore the trees, rocks, earth, herbage, &c. should always be etched, or, at least, as much as conveniently can be done; nothing left for the graver but the perfecting, softening, and strengthening. And, in most subjects whatever, the shadows ought to be etched, and the lighter tints finished with the graver, dry-points, &c.

Of Whetting and Tempering the Graver. It is necessary that the artist understand how to choose a good graver, to whet it when requisite, and to temper it when too hard. The two sides, which form what is called the belly of the graver, are more or less angled, and their extremities form the point. When ground, the breadth of the end is termed its face. In whetting the graver, great address and care is requisite:—The two lower angles of the graver are to be laid flat upon the oil-stone, and rubbed steadily, until they are as bright as a mirror, and till the belly rises gradually; so that when the graver is laid flat upon the plate, the light may be perceived under the point; otherwise it will dig into the copper, and it will be impossible to use it with freedom. The face is next to be whetted, which is done merely by laying the face of the graver flat upon the stone, with the belly upwards, and rubbing it steadily upon a moderate slope, until it acquire a very sharp point, which may be tried on the thumb-nail; observing that the stone be supplied with oil during the whole time. Gravers, as sold in the shops, are generally too hard for use, which may be known by the frequent breaking of their points. When this is the case, they should be tempered, by holding them on a red-hot poker, till they change to a light straw colour, and then dipping them in oil: or they may be held in the flame of a candle, and cooled in the tallow. The gravers, which are so soft as to yield to a file, are worth nothing.

Of Etching, and Preparation of Grounds.

Etching is a species of engraving, and of a more modern invention than that performed by the tool only. It is effected principally by the corrosive quality of aqua-fortis: the copper-plate being first covered with a resinous ground, which preserves the metal from the action of that powerful menstruum, while other parts of the plate are exposed to its influence, by lines drawn, with proper instruments, through the ground: and by the greater or less action of the acid spirit on the plate different excavations are effected, and the plate is rendered capable of displaying the different tints of light and shade, or all the beauties of the *chiaro oscuro*. The first operation in this art is the laying on the ground. Several recipes have been given for the forming of this composition; and among those who profess the art there is a great diversity in their preparation of the ground. It is an article of great importance to the engraver, and deserves his principal consideration. Here we give the composition of the most generally approved grounds, leaving the artist to his predilection, as his own choice or experience may direct him.

Rembrandt's Ground.—Take of asphaltum, burnt, half an ounce; and the same quantity of gum-mastic, pulverize or beat them to a fine powder; and add them, by degrees, to one ounce of virgin-wax, melted over a gentle fire, stirring the composition till the whole be thoroughly incorporated: which, when intimately compounded, pour into clean water, and make it into balls for use. When this ground is used, it should be laid on the plate very thin; and the plate must not be made too hot.

Callot's Ground.—Take a quarter of a pound of virgin-wax, and two ounces of asphaltum, the same quantity of mastic, one ounce of resin, one ounce of shoemaker's pitch, half an ounce of common pitch, half an ounce of varnish; melt the wax, and add the other ingredients as before, and when incorporated pour it into water.

Another ground in very frequent use.—To a quarter of a pound of virgin-wax add the following ingredients: two ounces of asphaltum, one ounce of amber, and one ounce of mastic. The asphaltum and mastic must be reduced to a very fine powder, as before, and gradually mixed with the wax, which is melted over a gentle fire. The composition is then poured into water, and made into balls as the others. Some use a ground formed only of six ounces of virgin-wax, four ounces of mastic, and two of asphaltum, prepared as above directed. The ground generally used by engravers is one of the foregoing; but it must be observed, that the ground should differ in consistence according to the temperature of the weather, being made harder in summer, and of a softer nature in cold weather.

When the ground is to be laid on, the plate must be heated to a sufficient degree, either over a charcoal-fire, or by a fire of common coal, so that it may not be smoked. For this purpose a hand-vice is fixed to the most convenient part of the plate, by which it may be held in the hand. When the plate changes colour, or rejects the fluid when spit upon, it is sufficiently heated. The ball of ground is then rubbed on, being tied in a piece of thin silk; and, as it is rubbed gently over

the plate, the heat melts the composition through the silk, and the rubbing is continued till it be distributed over every part of the plate. The ground is then beat with the dabber, (which is a piece of cotton tied up in silk) to render it perfectly smooth, and uniformly thin throughout. Great dexterity is required in dabbing the ground, to render it of an uniform thickness; for, if some parts be thicker than others, it will deceive the engraver in his etching, and biting-in of his work. The ground is next to be smoked, by holding it over the flame of a lamp, which emits a copious vapour, or two or three common candles united together will answer the purpose; observing to move the plate about, so that the smoke may pervade every part of the ground. The plate being cold will be ready to receive the outlines of the print, or drawing, which is to be traced on the ground in the following manner:---Rub the back of the print, drawing, or design of which you intend to engrave a plate, with the scrapings of red chalk, or flake white or black-lead powder, or any other substance which will readily impart a legible mark, then place this coloured side of the drawing upon the ground of the copper-plate, making it fast at each corner with soft wax. Place the small board, called the *etching-board*, over that part of the drawing upon which you are not employed, to rest your hand upon, to prevent your hand bruising the ground; and, with a blunt etching-needle, trace lightly the outlines of the drawing, and also the breadth of the shadow; and the back of the drawing, which is coloured, will communicate similar lines to the ground of the copper-plate. The tracing must not be performed too heavily, otherwise the ground will be broken. During the operation of tracing it is necessary frequently to lift up one corner of the drawing, to examine whether every part be traced, before the drawing be taken off the plate; as then it would be very difficult to replace it in its former position. The tracing being completed, the drawing is to be removed, and the subject is ready for etching.

The principles of etching are very simple, and are easily performed by those who have but a moderate proficiency in the art of design, being little more than drawing the outlines through the ground upon the copper with a pointed needle. There are several of these instruments employed in the art, according to the breadth of the strokes required to be made. They are nearly similar to sewing needles; but stronger, and inserted into handles from four to five inches long. They are formed with various points; some being round, and others oval, which have each their separate use. The former being used for fainter, and the latter for darker strokes. Having laid a piece of silk or linen next the plate, and over that the etching-board, proceed to etch the work, beginning with the fainter works, which are to be worked closer, and with a sharper pointed needle; next proceeding to the darker points, which must be etched wider, and with a blunter needle. In buildings and architecture in general, straight and parallel lines should be drawn with a straight or parallel ruler, except the etcher have a very steady hand, and have had considerable practice. Lines, drawn in etching, may, in general, be crossed by other lines, if required. Two parallel lines, drawn close together, will unite into one when biting, and form one strong line of great breadth and colour: This mode of making black lines is very serviceable in dark fore-grounds in landscape, and sometimes has a good effect in architecture: but, in historical subjects, etching is chiefly used to prepare the figures for the graver, which it

performs with much facility, and gives the piece an appearance of greater freedom than could otherwise be effected.

Etching, though expeditiously performed, has several advantages above engraving. It is true, that it possesses a certain roughness of appearance, compared with engraving, and therefore does not suit subjects which require a gloss or lustre: but it has an excellent effect in most representations of uncultivated nature, as in landscape, the broken and loose touches of fore-grounds, the barks of trees, &c. It very happily expresses the ravages of time in old buildings, ancient castles, mouldering walls, and the like. The freedom of its appearance renders it very appropriate for expressing the leaves of trees, light clouds, &c. It is very valuable for possessing a true, even, and uniform colour, for which it may be depended upon more than the work of the graver only; by which quality it obtains in the blue parts of skies, and also where an even tint is wanted in new architecture, back-grounds to portraits, and many other grounds where the parallel-ruler is used.

Directions for Biting.

The work being etched, the plate is next to be corroded with aqua-fortis: a border of soft wax (composed of melted bees'-wax, tempered with one-third or one-fourth of its quantity of Burgundy pitch, or with a little Venice turpentine and tallow) is to be raised upon the plate, round the work, in the form of a mound or wall, to inclose the aqua-fortis, and prevent its running off. A gutter is usually made at one corner of the plate, for pouring off the aqua-fortis, when requisite, but which is stopped up with a little wax or tallow, during the time the aqua-fortis is to remain on the plate. The plate being thus bordered, some common refiner's aqua-fortis is to be mixed with half its quantity of water, and poured gently upon the plate, till it rises about a finger's breadth above the surface of the ground; when, if all things have been rightly conducted, it will be seen that the menstruum will soon begin to exert itself in the hatches which have been more strongly touched: but the more faint strokes will appear for some time clear, and of the colour of the copper. The aqua-fortis must, therefore, continue on the plate till it appears to have acted on the tender and finer parts of the work. And during the time it remains on the plate it should be gently agitated by a feather, with which the operator should cleanse away the foulness of the verdigrise that gathers in the hatches, when the aqua-fortis exerts its influence: by which means the hatches will be cleansed, and the menstruum will act with greater force, and more equally on every part of the plate. When you think the work is sufficiently bitten, pour off the aqua-fortis, and wash the plate carefully with water: when dry, scrape off part of the ground from some of the faintest parts of the work, to see if it be sufficiently corroded; and if it be not bitten enough, stop out the part you have examined with a hair pencil dipped in a mixture of Venetian varnish and lamp-black; and when that is dry pour on the aqua-fortis again.

When the faint parts of the work are excavated to a proper depth, stop them out with the Venetian varnish, and proceed to rebite the stronger parts, by pouring on the aqua-fortis again; and proceed to stop out other parts, and again bite others, if requisite, till the whole

work is sufficiently corroded. Then warm the plate to take off the border of soft wax; after which make it sufficiently hot to melt the ground, then, by pouring on it a little olive oil, the whole may be wiped off with a linen rag. The ground being taken off, the plate is to be well rubbed with the oil rubber, and wiped clean: lastly, it is to be finished with the graver and the other dry tools, if the subject require it, which is generally the case. In biting a plate the greatest attention is necessary: for if it be under-bitten, or, in other words, if the parts have not attained their proper depth of colour, there is usually no other remedy than that of following every line with the graver, in order to blacken it: on the other hand, if a plate be over-bitten it can never be rendered neat and delicate, though ever so much time and skill be bestowed upon it: but if it be bitten only a little above the colour intended, a few strokes of the burnisher will generally reduce it to a perfect tint.

Several precautions are necessary to the inexperienced in this art, in the different parts of the process:---it is necessary that the plate be perfectly clean and free from any greasy spots before the ground be laid thereon, as grease prevents the ground from adhering to the plate: it should, therefore, be well cleaned with whiting, which must be again wiped off before the ground be laid thereon: the plate should not be made too hot, when it is to receive the ground, otherwise the ground will be burnt, and will then have a scorched appearance. In smoking the ground over the lamp, or candle, care must be taken to hold the plate at a proper distance from the flame, that it may not be scorched, which will easily be seen by the ground appearing burnt, and losing its gloss; yet the whole ground must be smoked before the plate grows cold, for it is necessary that it be in a fluid state during the operation of smoking: if it become cold, it must be heated again; or, if it appear that the smoke has not penetrated the ground, the plate must also be again gently heated, when it will be perceived, that, in proportion as the plate grows hot, the ground will melt and incorporate with the black which lay above it, in such a manner that it will be pervaded by it throughout every part. The expedition which is necessary in smoking the ground is the reason why three or four candles, a flambeau, or strong lamp, must be used. And where a plate is very large, it is expedient to suspend it from the ceiling of a room, by four strong cords fastened together at the top, having an iron ring of about four inches in diameter to each, which sustains each corner of the plate, and which is suspended with the varnished side downwards. In this situation it may be blackened very conveniently, by only moving the candles or flambeaus to the different parts of it: and during the whole time that the ground is warm, the operator must be careful to keep from it all dust or filth of any kind which would stick fast thereto, and greatly injure his work. In tracing his drawing, he must be careful of bearing too heavily on his work, lest he break his ground. In the management of his aqua-fortis great address is requisite; and experience is absolutely necessary to manage this powerful agent with success. In making the ground, the ingredients must be melted over a slow fire; and while the asphaltum is putting in, and even after it is mixed with the other articles, they should be constantly stirred with a spatula, and suffered to simmer gently, till a drop put on a plate will break between the fingers when cold: the water into which the composition is

poured, should be nearly of the same warmth with the articles, to prevent a kind of cracking which would otherwise happen in the ground, when finished. If any scratches or false strokes happen in the working, they are to be stopped up with the Venetian varnish and lampblack, by which means they will be defended from the action of the aqua-fortis.

A variety of needles, or pointers, is necessary, some with points as sharp as those of common needles, for the very fine lines. Those used for broad large strokes should be very blunt, exceeding round, and well polished at the point. The sole of a shoe answers very well for polishing the pointers; but they should be whetted upon the oil-stone, some with a more blunt, and others with a sharper point, according to their respective uses, and which requires considerable address. The pointers may also be numbered according to their uses.

There are, generally speaking, two kinds of etching, the one above mentioned, called etching with the soft ground, to distinguish it from the other, or etching with the hard ground. The former has now prevailed nearly to the exclusion of the latter, except in the case of particular subjects. The hard ground was formerly much in use, though it be, undoubtedly, a more modern invention than the etching with the soft ground. It was, however, more admired than the other species, on account of the practice more nearly resembling the work of the graver; as the firmnes of the ground enabled the artist to retouch the lines, or open them when too narrow with the oval-pointed needles.

Engraving in Chalk.

This method of engraving has lately, very deservedly, merited public attention, by the beauty of many specimens it has produced. It may be considered as a method of etching in dots, since the preparation of the plate, laying the ground, tracing the subject, &c. is the same as in etching. The principal difference is, that instead of lines, as in etching, the drawing, shadows, &c. consist of a mixture of varied and irregular dots, as freely as can possibly be done, yet carefully, and made more or less soft, so as to resemble the grain produced by the chalk on paper. For every stroke of the chalk on paper may be considered as an infinite number of adjoining points, which are the small eminences of the grain of the paper, touched by the chalk in passing over it. The plate being prepared, and the ground laid as in etching, the drawing to be imitated may be counterproved on the ground of the plate. If this cannot conveniently be done, black-lead pencil, or red-chalk, must be applied to varnished or oiled paper; by which means all the traces of the drawing may be transferred to the ground. The outlines of the drawing must be formed in the etching by points, which will create dots, whose size and distances must be determined by the quality of the strokes of the original drawing. In forming the lights and shades, it is necessary to distinguish between those hatches which serve to express the perspective of the object, and those which form the ground thereof. The principal hatches must be more strongly marked; the middle tints, if etched, marked lightly, or they may be left to be finished by the dry-needle and graver after the ground is taken off, which will give them a greater degree of softness. In applying the aqua-fortis, the artist should be

careful not to corrode the lighter parts too much. When these parts are sufficiently bitten, they may be stopped up with the turpentine varnish and lamp-black; and the aqua-fortis may be applied again to bite the stronger parts; and it may be observed, that if the dots which compose the shade burst into each other, it will not injure the work, except they form too hard a spot, or too considerable a black. When the ground is taken off the plate, it will be necessary to interstipple with proper points in the flesh, and softer parts of the work, which will produce a more delicate effect than can ever be attained with the aqua-fortis alone: the strongest shades will also require additional strength, and must, therefore, be deepened by slight strokes of the graver. The graver is the only tool that can be depended upon in finishing small subjects which require neatness. The best manner of preparing it is by changing its situation in the handle, so that the belly part of it, which was lowermost, becomes uppermost; then, by turning the handle in the hand, the point acts upon the copper from a greater elevation, which is preferable; as dots only, and not strokes, are required, the tool is managed in this position with much greater ease and freedom. This part of the operation consists only in covering the copper with dots in a manner, lighter or heavier, proportionate to the colour required. When one covering of dots is scraped off, another must be inserted, and so on: by this repetition, a proper grain and sufficient masses of shade are procured. Though the process is tedious, it requires no very great skill in the artist: care, attention, and practice, will enable him to succeed.

This species of engraving admits of greater variety in the mode of executing it than either etching or engraving with the tool. Of those who profess it, every one has a peculiar method of performing some particular part. In large subjects, and also in those where a general effect only is wanted, and great exactness is not required, some persons use various tools for facilitating their work, such as wheels having single or double rows of teeth at their edges, cradles resembling a mezzotinto grounding-tool, (but made with teeth) and sometimes others constructed according to their own minds: but these tools, though more expeditious than the graver, seldom produce a very good effect, and can never be depended upon, in any degree, for accuracy or neatness.

It will sometimes happen, particularly to him who is not well practised in the art, that those parts which were intended to be dark fail in their proposed effect, which is sometimes the fault of the tool, the ground, or the aqua-fortis, but more frequently of the inexperience of the artist. When this is the case, the plate may be re-bitten by heating the plate, and, at a convenient part thereof, melting a quantity of ground and with a dabber carefully by degrees, transplanting it, by beating it gently to the parts proposed, so that the surface only of the copper may be covered, and the hollows or excavations of the work may be free and clean. When the plate is cold, it may be rebitten with aqua-fortis as before. It is advisable not to smoke it in this operation, lest the heat of the candle or lamp melt the ground into the work. This method of re-biting the work is used not only in engraving in chalks, but in every species of engraving where aqua-fortis is used, and in every kind of etching, and is among the secrets of the superior engravers. To clean engraved strokes, they should be washed with a little spirit of turpentine; if the dirt is of long standing, soap-lees poured on the plate while it is heating will be very effectual

in clearing away the dirt. But it must be immediately washed off with plenty of cold water, otherwise it will injure the work; it is also too strong for mezzotinto plates, unless used very carefully, and not suffered to continue long on the plate.

The chief merit of engraving in chalks is to form a kind of deception, which, when well executed, it does very successfully, so that the connoisseur is hardly able, on the first inspection, to distinguish between the original drawing and the engraving made in imitation of it. It is extremely useful, as it serves to multiply copies of drawings left by those masters who excelled in the use of chalks, and furnishes young artists with the same assistance in the practice of drawing as if they had access to the original. Drawing also made with chalks of different colours may be imitated in this manner, if a plate be provided for every colour. The French have very well imitated drawings on blue paper, by using two plates, one of which printed the black chalk effect, the other that of the white chalk. Chalk-plates, likewise, printed in black on blue paper, may afterwards be touched with white chalk, whereby they will have a very pleasing effect.

Of Mezzotinto Scraping.

Prince Rupert is generally reported to have been the inventor of this art, and is said to have received the idea from seeing a soldier polish his rusty arms with a file. But Baron Heinikin, a very judicious and accurate writer upon the subject of engraving, asserts, with great appearance of truth, that it was a lieutenant-colonel De Siegan, an officer in the service of the Landgrave of Hesse, who first engraved in this manner; and that the print which he produced was a portrait of the princess Amelia Elizabeth of Hesse, engraved in the year 1643. From the writings, however, of the best informed upon this subject, we find that Prince Rupert learned the secret from that gentleman, and brought it into England, when he came over the second time with Charles II. His print of an executioner holding a sword in one hand and a head in the other (a half length, from Spagnoletto) is dated 1658. This art has never been cultivated with such success in any country as in England, and is one among the many valuable improvements in art, which owes its present state of perfection to the fostered genius of Britain.

Prince Rupert, though so early in the art, succeeded better than many of his followers. He laid his ground with a channelled roller, upon the same principle as the present grounding-tool; but one Sherwin, about the same time, laid his grounds with a half-round file, which was pressed down with a heavy piece of lead. Both these grounding-tools have been laid aside for many years, and the present grounding-tool introduced, which, in its form, resembles a shoemaker's cutting-board-knife, with a fine crenelling on the edge. This was the invention of Edial (a smith by trade) who afterwards became a mezzotinto printer.

This art merits attention, from the facility with which it is performed, and its beautiful and soft effect. The operator rakes, hatches, or punches the surface of the plate all over with the instrument made for that purpose, first one way, then the other, across, &c. till the surface of the plate be thus entirely furrowed with dots; close, and, as it were, contiguous to each other; so that, if an impression was then taken from the plate,

it would be one uniform blot or smut. The design is then drawn or marked on the same face; after which, with burnishers, scrapers, &c. the artist proceeds to expunge and take out the dents or furrows, in all the parts where the lights of the piece are to be thrown: and scraping it more or less, as the lights are to be stronger or fainter; leaving those parts black which are to represent the shadows or deepening of the draught.

The great facility with which mezzotintos are executed is evident from the nature of the operation; for it is much easier to scrape or burnish away parts of a dark ground, corresponding with any design sketched upon it, than to form shades upon a light ground by an infinite number of hatches, strokes, and points, which must all terminate with exactness on the outline, as well as differ in their force and manner, as is the case in the other kinds of engraving: the method of scraping in mezzotinto, consequently becomes much more easy and expeditious than any other manner of engraving. The instruments used in this kind of engraving are cradles, or grounding-tools, scrapers, and burnishers.

Particular Directions.

Notwithstanding the great difference in the works of the mezzotinto engravers, their operations are nearly the same. The plate must be prepared and polished in the same manner as for other work; and afterwards divided equally by lines parallel to each other, which are to be traced out with very soft chalk. The distance of these lines should be about one-third of the length of the face of the cradle, or grounding-tool, which is to be used; and they should also be marked with capital letters, or strokes of the chalk, to distinguish them from one another. The cradle is then to be placed exactly between the two first lines, and passed forwards in the same direction with them, being held as steady as possible, and pressed upon with a moderate force, rocking it from end to end, till it has completely hacked all that part of the plate between those two lines. The same operation must be repeated with respect to all the other lines, till the instrument has thus passed over the whole surface of the plate, and rendered it uniformly rough throughout. Other lines must be then drawn from the extremities of the other two sides, in the same manner, and at the same distance from each other, as the first set of lines; these lines intersecting the first at right angles, will, with them, form squares. The same operation must be repeated with the cradle, between this second course of lines, as in the case of the first. New lines must then again be drawn diagonally to the former, and bisecting the aforesaid squares, and the cradle passed betwixt them as before: when the first diagonal operation is performed, the diagonal lines must be crossed at right angles by other lines, as the former, and the cradle passed betwixt them in the same manner. The plate having undergone the action of the cradle, according to the disposition of the first order of lines as above, a second set of lines must be formed, having the same distances from each other as the first. But they must be so placed as to divide those already made, into spaces one-third less than their whole width; *i. e.* every one, after the first on each side, will take in one-third of that before it; *e. g.* beginning at A, of which the first third must be left out; a third of B will consequently be taken

in, and so of the rest. These lines of the second order must be marked with small letters, or lesser strokes, to distinguish them from the first: and another ground must be laid on the plate, by hacking it with the grounding-tool, between each two of the second order of lines. When this second operation is finished, a third order of lines must be made; the first of which, *e. g.* in A, must omit two-thirds of it, and consequently take in two-thirds of B, &c. By these means the original spaces will be exactly divided into equal thirds; and the cradle must be again employed betwixt these lines as before. When the whole of this operation is finished, it is called *one turn;* but in order to produce a very dark and uniform ground, the plate must undergo the repetition of all these several operations for above twenty times; beginning to pass the cradle again betwixt the first lines, and proceeding in the same manner through all the rest. The plate being thus prepared with a proper ground, the sketch of the design, or outline, must be chalked on it, by rubbing the back of the paper, or drawing with chalk, and tracing the outline with a pointer, as in etching. It is also proper to overtrace it afterwards with black lead or Indian ink, to have a more distinct and permanent sketch. The scraping is then performed by paring or scraping away the grain of the ground in various degrees, so that none of it is left in the original state, except in the touches of the strongest shade The general method of proceeding is similar to that of drawing with white upon black paper. The masses of the strongest light are first begun with, and scraped pretty smooth; and some parts, where there is no shade, as the tip of the nose, &c. are burnished, and those parts which go off into light in their upper part, but are brown below. The next lower gradations of shade are then scraped down, after which the reflections are entered upon: the plate is next to be blackened with a printer's blacking ball, made of felt, in order to discover the effect: and then the work is proceeded with again, observing always to begin every part in the places where the strongest lights are to be introduced.

Of Aqua-tinta.

This method of etching on copper is a modern invention; more facile in its operation than any manner of engraving or etching hitherto known, and produces a more beautiful and soft effect, resembling a drawing in water colours or Indian ink, of a more soft and delicate nature than mezzotinto. The first person who finished any pieces of this kind, that had a soft appearance, and at the same time would print any considerable number of impressions, was M. Le Prince, of Paris, who produced some specimens of his work in his *Modes et Usages de Russie.* He still further improved this important discovery; and at length the honourable Mr. Greville, brother of the Earl of Warwick, struck with the novelty of the invention, purchased the secret of M. Le Prince, for the sum of thirty guineas, and communicated the process to the ingenious Mr. P. Sandby, who had before attempted it, but with little success: his genius, however, so far improved upon the method of Le Prince, that he soon produced pieces of considerable excellence. The lightness and simplicity of the effect attracted admiration from the amateurs of art; and many ingenious engravers, as well as artists, considered it an object worthy of their pursuit, and endeavoured to render them-

selves masters of the art. Hence several new methods of working in aqua-tinta were invented, each of which had its followers and partizans, which produces that great variety and difference observable in their works.

In this branch of etching nearly the whole of the work is performed by the corrosive quality of the aqua-fortis on the copper: for after the mere outline is obtained, there is no use for the graver, needles, burnisher, scraper, or any other tool, the different shades being effected by the greater or less action of the aqua-fortis on the copper; the fainter parts, having been sufficiently bitten, are stopped up, while the menstruum again exerts itself on the next stronger shades; and these are again defended by the varnish, while the still darker shadows are corroded.

The method of regulating the action of the aqua-fortis on the plate is by covering it sparingly with a fine powder of a resinous nature, which, when warmed, will adhere to the copper, and defend it, in all the points of contact, from the corrosion of the spirit, while the minute spaces between those points will be excavated: therefore, most resinous bodies will answer this intention in a greater or less degree. Common rosin, finely pulverized, was first used, and sometimes (where the work was not very delicate) with tolerable good effect; but this substance, if too finely powdered, is apt, when warmed, to form a coat or superficies to the plate, and thereby resists the menstruum altogether; wherefore sal ammoniac, mingled with it, was found to preserve interstices; but this mixture did not fully answer the intention.

The copper-plate must first have a common etching ground laid upon it, and the outlines of the design etched thereon, and bitten with the aqua-fortis, as directed in the operation of etching. The ground must then be softened with a little grease, (the plate being gently warmed if necessary) and wiped with a linen rag, suffering as much grease to remain on the plate as to take off the glare of the copper. You must now carefully and sparingly sift a layer of powdered rosin and asphaltum upon the surface of the plate, which will sufficiently adhere to the copper by reason of the grease left thereon; then strike the other side of the plate pretty briskly against the edge of the table or desk, which will discharge from it all the loose and superfluous powder: next hold the back of the plate, by means of a hand-vice, over a chafing-dish of charcoal, till it become so warm, that it cannot be held long against the back of the hand, without exciting pain: the powder will now adhere firmly to the copper, and will not unite together, if the plate be not too hot. When the plate is cold, with a hair-pencil dipped in Venetian varnish, mixed with lamp black, cover all those parts of the piece which are to be left perfectly white, or where there is no shade. Raise a border of wax round the plate; and having reduced the aqua-fortis to a proper state, by diluting it with vinegar or water, pour it on the plate, and let it remain there for about five minutes, which will be sufficient to produce the first or lightest tint. The spirit must then be poured off, the plate washed in fair water, and set on its edge to dry. With the varnish now stop up all the lightest shades, and pour on the aqua-fortis as before for the second tint; and after letting it stand about five minutes, pour it off, and again wash and dry the plate; proceed in the same manner for the third tint; and also for the following, if more than three be required, until the darkest shade be produced. Sometimes a

bold open ground is required in part of the work; when this is the case, another ground must be laid on that part of the plate, by sifting coarse powder, or even rosin alone thereon, and the plate must be heated to a greater degree: all the other parts of the plate are then to be stopped up with the varnish, and the aqua-fortis suffered to act only where the coarse ground is laid, and where, consequently, the shade will be much bolder. The sky and distant objects in landscape, which require to be faint, are also performed by a second operation; but with this difference, that they require finer powder, and to be laid on with a finer sieve; the plate must likewise be less heated than in the general method. When any parts require to be higher finished, as is sometimes the case in the trees, and in objects in the fore-ground, the plate must be entirely cleansed from grease by rubbing it with some crumb of bread: a common etching ground is then laid thereon, and the work finished with the needle or point, and bit in with aqua-fortis; and sometimes finished with the dry point only, in which manner it may be rendered as neat as possible.

The Preparation of the Powder for the Aqua-tinta Ground.

Take of asphaltum and fine transparent rosin equal parts, and pound them separately. Through a muslin sieve sift upon a sheet of paper a thin stratum of the asphaltum, upon which sift a similar layer of the rosin; upon this again another layer of asphaltum, and so on alternately, continuing these alternate layers till both of the powders are exhausted: then pass the mixture through the same sieve once or twice, or till both appear to be sufficiently incorporated, when it is ready for use. Instead of this powder some use gum sandarack only. But when the above mixture is used it is absolutely necessary that the rosin and asphaltum be sufficiently mixed together, otherwise they will not act equally on the copper, and by that means greatly deceive the artist.

The following is the method recommended by M. Le Prince, which certainly deserves attention, not only for the novelty of the invention, but also for its success in many instances; and however it may have been superseded by other discoveries, it has, and still affords, a useful hint to the artist. Reduce a sufficient quantity of gum juniper (though gum copal is now preferred) to a fine powder, and divide it by sifting it through three or four sieves, of different fineness, into as many respective parcels. The finest powder serves for the lightest shades; as very distant objects, the sky, &c.; the next coarser powder for the middle tints; and the coarsest for fore-grounds and the deepest shadows. The outlines being etched on the plate, in the common manner of etching, and the copper greased as directed in the foregoing method, sift on the plate a layer of the finest powder; shake off the superfluous part by striking it against the table, and heat the plate gently, till the gum changes colour, when it will be sufficiently melted to adhere to the copper, then stop up all the lights or places where there is to be no work when cold, raise a border of wax round the plate, and pour on the aqua-fortis for the first tint, which is to remain on the plate about five minutes, and then poured off, and the plate warmed and perfectly cleaned from this first ground, by adding a little oil if necessary: the lighter tints being finished, they must also be stopped up, as well as the blank parts of

the copper, and the second powder sifted on the plate, the copper heated, and the aqua-fortis poured on as before, to produce the second tint. The coarser powder, or rather grains of gum, must also be heated in the same manner.

The difference of the powders creates a difference of tints; for the coarser and larger the grains are, the more firmly they adhere to the copper, and their contact with the plate occupies a larger surface; they also permit more copper to be corroded away from around them by the aqua-fortis: but if a ground were not previously laid by the finer powders, the coarse powder would produce very staring whites, or if the gross powder were misplaced, it would greatly disfigure the piece. The gross powder also requires the plate to be more heated. A larger grain of white may be produced by melting the finer powder more than usual, which makes the particles spread, and occupy a larger surface. Sometimes a finer tint may be laid over a coarser one with very good effect, as well as a coarse one over a finer. In this method of working, any part of the plate may, at any future time, be rebitten, if required, provided the other parts are securely stopped up; which is very useful to the learner, as he may improve and rebite his piece to his mind. The principal requisite is the skilful management of the varnish, which requires some patience and experience to enable the artist to stop up the lights and lighter shades in their proper places; as in a good piece the different shades are very often so much mingled and blended together. Le Prince's method is, however, certain in its operation, and generally rewards the student who pursues it diligently.

There are several other methods of working in aqua-tinta, devised by ingenious engravers, which do more credit to their invention, than bestow utility to art: the main process of two of the principal shall be given as they include the general principles of a numerous train.

One method is, by applying an acid capable of corroding the copper, without using aqua fortis: the operation is briefly this:—Mix a quantity of ground sulphur with oil, and lay the mixture on the copper with a pencil in the manner of painting, and in those parts of the design you wish to corrode: then, by placing the plate over a gentle fire, the vitriolic acid contained in the sulphur is set at liberty, and corrodes the copper: the plate is then washed clean, and again painted with the mixture in all the parts, except the lights and faintest tints, which latter have already been corroded: it is again exposed to the fire, and made somewhat hotter than before, which will answer the same intention as a second biting with aqua-fortis. The plate being cold and washed, it is to undergo another operation for the deepest shades, being made somewhat hotter than the last time, and exposed to the fire a longer time. In this mode of procedure, as it is observed that the acid in the sulphur acts on the copper more or less, in proportion to the heat, and the time it is suffered to continue on the plate, it must consequently remain longer on the copper, and the plate heated to a greater degree for the second tint than for the first; and still more so for the third than for the second. This practice of etching has not been much followed, on account of the inconvenience attending the operation, from the nauseous fumes of the heated sulphur; otherwise there is little doubt but this manner might have been rendered very successful for light subjects, and even for others, assisted with some darker shades for fore-grounds.

The other manner, invented by the ingenious in this art, is to satu-

rate a quantity of aqua-fortis, of a proper strength, with small particles of silver: this mixture is then to be poured on the copper, the outlines of the design being drawn thereon, and all the lights stopped up with the varnish, when the aqua-fortis will quit the silver it contains, in order to act upon the copper, to which it is more disposed; and the silver will precipitate in the form of a subtile powder, and defend the plate in the points of contact from the action of the menstruum, while the other parts will be excavated. The first tints are then to be stopped up, and a fresh quantity of the solution poured on for the second tint. The process is to be repeated for the third tint, and so on as often as is requisite. This manner is applicable only to very slender parts and faint pieces: it is used sometimes to add a colour to places which are not of sufficient importance to require a fresh ground, or where much trouble is not necessary; particularly in the leaves of trees, light flying clouds, &c.

Aqua-tinta is so expeditious a method of etching, that it will produce on a large plate, in one week, the effect of two months labour at some kinds of engraving. It is generally objected, that the work is but shallow on the copper; however, when skilfully executed, and carefully treated by the printer, it is sufficiently lasting. It possesses a very even and uniform colour; smooth, and free from blemishes; and has a very good effect in landscape in particular, of every kind; applies very well to architecture, and back-grounds in general: in the latter form, viz. in back-grounds and distant objects, it has been successfully introduced by several good engravers in their large pieces, where the whole work was intended to pass for an engraving.

The foregoing is a general account of the process of engraving in aqua-tinta, in which few circumstances are omitted that can be expressed on paper: but after all, no printed directions whatever can enable a person to practise it perfectly, without witnessing the operation. Its success depends on so many niceties, and requires attention to so many particulars, apparently unimportant, that the student must not be discouraged if he does not at first succeed. It is a species of engraving simple and expeditious, when every thing goes on well: but it is very precarious, and errors in it are rectified very difficultly. It seems to be adapted chiefly for imitation of sketches, washed drawings, and slight subjects: but does not at all appear to be calculated to produce prints from finished pictures; as it is not susceptible of that accuracy in proportioning the tints which is necessary. Nor does it seem adapted to book-plates, as a large number of impressions cannot be taken from it. Aqua-tinta ought not, therefore, to be placed in competition with the other modes of engraving: but when confined to certain subjects, it must be allowed to be extremely useful, being expeditious and easily attainable. This last circumstance is, however, often a source of mischief, as it occasions the production of a multitude of prints, calculated only for vitiating the public taste.

ENGRAVING ON WOOD.

Engraving on wood is a process exactly the reverse of engraving on copper. In the latter, the strokes to be printed are sunk or cut into the metal, and the impressions are taken off by means of the *rolling-press:* but in the former kind of engraving all the wood is cut away, excepting

those parts on which are drawn the lines to be printed. These parts stand up or project, like the letters on printing types; and the mode of printing is the same with that used in letter-press printing. The wood used in this species of engraving is commonly box very smoothly planed. The design is drawn upon the wood itself with black-lead; and all the wood is neatly cut away with gravers and other tools, excepting where the lines are drawn. In some cases the design is drawn upon paper, and pasted on the wood, which is then cut away as before. On certain occasions, two, three, or more pieces of wood, or blocks, have been used in the same print; the first block containing merely the outline of the subject upon it, the second the darker shadows, and the third the shadows terminating on the lights. These several blocks were employed in succession, each print receiving an impression from all the three: a mode of engraving intended to imitate the drawings of the old painters. The art of engraving on wood is in appearance extremely simple: like every thing else, however, it is extremely difficult to execute well; accordingly, few artists have hitherto excelled in it. By the *Bewicks*, however, of Newcastle-upon-Tyne, and a few other artists, engraving on wood has, of late years, been brought to very great perfection. This art cannot be made to supply the place of engraving on copper in every case; it is, nevertheless, very useful for geometrical and some other figures for books; because from the wooden blocks moulds may be formed, in order to cast metallic plates containing the figures, to be introduced among the letter-press, and printed off along with the types of the page.

Having mentioned the *rolling-press* employed in taking impressions from engraved plates of copper, the following general description of an implement of great value, but only to be found in London, Edinburgh, and a few other places, may be of use to many readers who have not had opportunities of seeing its construction and operation.

The rolling-press consists of two parts, the body and the carriage. The body is formed of two cheeks, commonly about four feet and a-half high, a foot thick, and two feet and a half asunder, connected together at each end by strong cross-pieces. The cheeks stand perpendicularly on a wooden foot, lying horizontally and sustaining the whole press. From the foot likewise rise four other perpendicular pieces, joined by horizontal cross-pieces, which may be considered as the carriage of the press, because they support a smooth even plank, about four feet and a half long, two feet and a half broad, and an inch and a half thick; on which the engraved plate is to be laid. Into the cheeks go two wooden cylinders or rollers, (from which the press has its name) about six inches in diameter, having their ends reduced to a diameter of two inches, and called trunnions, which turn round in the cheeks, between two semicircular pieces of wood, lined with polished iron, to facilitate the turning of the rollers. The space in these semicircular pieces or half-moons left vacant by the trunnion, is filled with paste-board, paper, &c. that they may be raised or lowered at will; so as only to leave the space between them required for the passage of the plank charged with the copper-plate, the paper to receive the impression, and the blankets. Lastly, to one of the trunnions of the upper roller is fastened a cross consisting of two levers or pieces of wood traversing one another at right angles. The arms of this cross serve in lieu of the handle of the common printing press, giving motion to the upper roller, between

which and the under is introduced the plank with the plate, &c; and by this motion both rollers are made to turn in contrary directions, and the plank is protruded or drawn through between them, and the plate is consequently pressed with equal force in every part.

In printing from copper-plates the usual practice is this. The workman takes a small quantity of the ink on a rubber made of linen rags, strongly bound together, and with it smears the whole engraved face of the plate, lying on a grate over a charcoal fire. The plate being sufficiently inked he wipes it first with a rag, then with the palm of the left hand, and then with the right; and to dry the hand and forward the wiping, he rubs it from time to time in fine whitening: and in this consists the address of the workman, that he wipe the plate perfectly clean on the smooth surface, without taking out the ink that has filled the lines of the engraving. The plate now prepared is laid on the plank of the press; over it is placed the paper, first moistened, to receive the impression, and over the paper are laid two or three folds of elastic flannel. Things being thus disposed, the arms of the cross are pulled, and by this motion the plank with its furniture is forced through between the rollers, which pinching very strongly but equably upon the elastic flannel or blanket, press the moistened paper into even the finest strokes of the engraving, whence it absorbs the ink, and receives a complete impression of the plate.

Drawing of Maps and Charts.

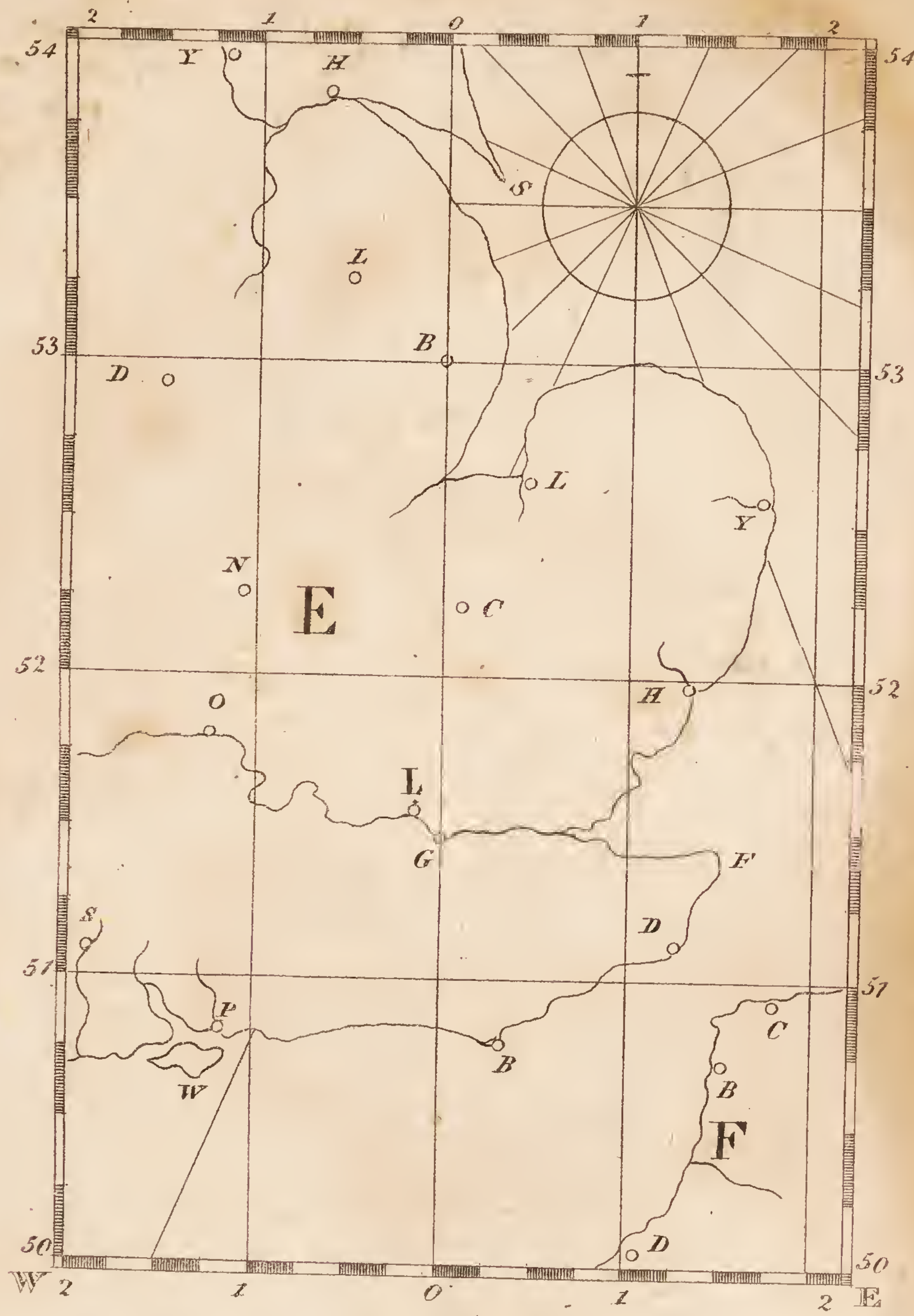
This earth being of a globular or spherical figure, it can be properly represented by a similar globe or sphere alone. It is not, however, a perfect sphere, in which every point of the surface is equally distant from the centre. Suppose we form a perfect sphere of clay of such a consistency that, when made to revolve with rapidity round a rod or axis passing through its centre, its parts may acquire a gradual motion among themselves. If this rapid revolution be continued for some time, and the globe be then examined, it will be found to have altered its shape; the clay will be found to have withdrawn from the parts about the ends of the axis, and to have accumulated towards the middle of the surface of the globe, in such a way, that another rod passing through this middle and the centre will be sensibly longer than the first rod, on which the globe revolved. Something of this kind seems to have happened to our earth when first produced, and before the various substances of which it is compacted had assumed the solid unchanging state in which they now exist. At any rate, it is now ascertained by the most accurate scientific measurements, in confirmation of the philosophic theory of *Newton*, that the earth is not a perfect globe, but a spheroid, having the diameter from N. to S. very sensibly shorter than that from E. to W. According to the latest observations, the axis on which the earth turns is about 35 miles, (or agreeably to some measurements only 27 miles) shorter than a diameter passing from E to W through her centre; so that her form bears a distant resemblance to an orange, flattened on the N and S, but swelling out in the middle between those points. But as on a figure of the earth, even 20 feet in diameter, this departure from the true globe would amount to only one inch, a difference totally im-

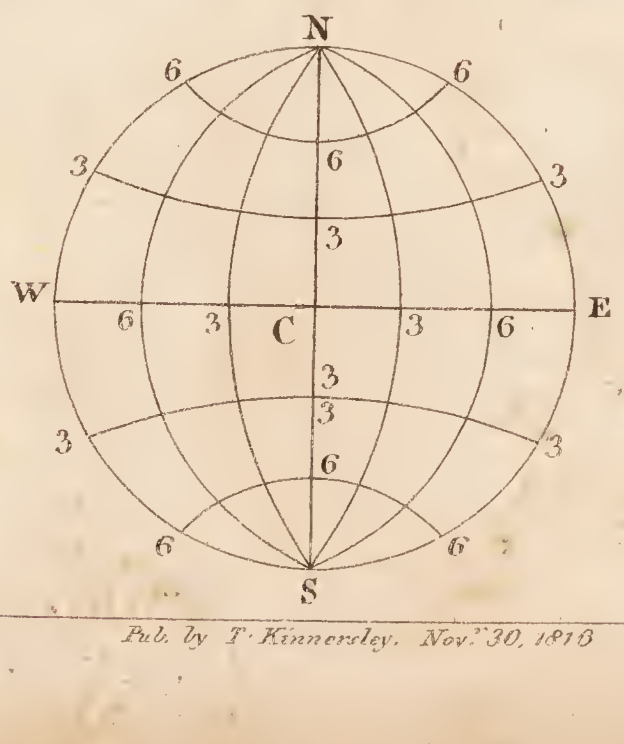
perceptible to the eye, it may be safely disregarded in all maps or charts however large the scale on which they may be drawn.

The earth being thus spherical, it is evident that no part of its surface can be strictly a plane. The tangent of a circle touches the circumference but in one point alone, and in all other points falls without it. Still, in small portions of the earth's surface, as an estate, a parish, or even a county, the figure of the ground will differ so little from a horizontal plane as not to be sensibly distinguished from it. If the difference between the position of a tangent to the earth's circumference, (that is of a true level line) and the spherical surface itself be calculated, it will be found, that even upon a distance of 20 miles, the difference between them is only 264 feet, or 88 yards, a matter of no importance whatever in maps or charts of that extent, which may therefore be laid down with sufficient accuracy on paper, or any other plane surface. When, however, it is required to make maps of the world, each containing one half of the globe, the one, for instance, comprehending Europe, Asia and Africa, and the other N. and S. America, it is necessary to give a representation corresponding to the appearance of the real globe of the earth, such as it would be perceived by an observer placed at a great distance above the ground. No observer, it is true, at whatever distance he may be placed, and however powerful may be his organs of sight, can ever view the entire half of the globe of the earth; in maps, however, this may be, and is taken for granted, and the several countries, seas, &c. are laid down conformably to certain geometrical principles, arising from the supposed distance and position of the observer.

These representations are called *projections of the sphere*, being of different sorts, according to the mode of projecting them, viz. 1st, the *orthographic*, or direct representation, (so called from an equivalent Greek term) in which the surface of one complete half of the earth is shewn, as if it were viewed by an observer placed at an indefinitely great distance, from whose eye the rays of sight proceed in parallel lines, each falling perpendicularly on the point of the globe to which it is directed. 2d, The *stereographic* projection, founded on the idea of representing a solid body on a plane surface, assumes the eye to be placed on the surface of the globe, supposed to be transparent as a ball of crystal, and looking through it to every point of the opposite surface. 3d, The *globular* projection is an attempt to combine the two former methods, by choosing a point of view or station for the observer, neither on the surface of the globe, nor at an indefinitely great distance from it. This point of view is supposed to be removed above the surface of the earth to a distance equal to the sine of 45 degrees, or 2800 English miles, measured on a scale of which the radius is that of the earth itself. In the orthographic projection, the parts of the surface occupying the middle of the hemisphere are shewn with tolerable accuracy, while those towards the circumference are more and more contracted beyond their due bounds as they approach to the margin. On the other hand, in the stereographic scheme, the parts in the centre are shewn more contracted, and those towards the margin more extended than they ought to be. In the globular projection, therefore, in which both these defects are in a great measure avoided, an approximation to a just representation tolerably correct is obtained, and now commonly adopted in spherical maps of the world. The representation (fig. 1. plate 1. of *maps*) of a sphere

MAPS.





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on this construction is drawn in this way. Upon C, the centre of the earth, describe a circle representing a meridian passing through the N. and S. poles, (N. and S.) and the E. and W. points (E. and W.) In this case NCS will be the axis of the globe, and WE the equinoctial. Divide the circumference of the circle into 360 degrees, or 4 quadrants of 90° each, as in the points 3 and 6, for 30° and 60° from the equinoctial on each side to 90° at the poles. Then divide the radii CN, CE, CS, and CW, each into as many equal parts in the points 3, 6, &c. Then draw the arches 6, 6, 6, and 3, 3, 3, &c. to represent the parallels of latitude; and in the same way draw the arches N 3 S, N 6 S, &c. to represent the meridians or circles of longitude. By this process, the area of the circle. NESW will be divided into spaces of latitude and longitude, as nearly of equal extent and capacity as can be desired. Consequently the parts of the earth drawn on a globular map of this kind will appear very nearly in their just relative proportions, an advantage not to be obtained by any other projection, constructed on the geometrical principles of perspective.

Such is the general nature of globular projection for maps of the whole earth: but for small portions of her surface other maps are used, in which the surface is taken to be not spherical, but a plane lying all in the same horizontal line. These are of two kinds, *plane* maps or charts, and those constructed on *Mercator's* principles. Were the surface of the earth a horizontal plane, it would, by the use of any common scale of equal parts, be an easy operation to lay down on paper a figure, bearing to the original tract of land the same proportion that a degree, a mile, a yard, &c. on the adopted scale, bears to the corresponding measures on the ground.

Plane maps or charts are constructed in this way. A line drawn along the bottom of the paper is divided into a number of equal parts, corresponding to the degrees, miles, &c. of longitude, intended to be brought within the map. On each end of this line are erected perpendiculars, on which are set off parts equal to those of the bottom line, to point out the degrees, miles, &c. of latitude to be comprehended in the draught. The same being done in the line joining the perpendiculars at the top, lines are drawn from right to left, and from top to bottom, through each of the marginal divisions, by which the paper is thrown into a number of square spaces, exhibiting the degrees, &c. of longitude and latitude, as every where of precisely the same extent. It will be evident, however, that the meridians on the globe of the earth, diverging in all directions from the poles to the equinoctial line, the spaces between them must be very different, in proportion to the distance of any particular point from that line; or in other words, that a degree of longitude is at the greatest at the equinoctial, and must be gradually shortened according to the increase of the latitude of the place of observation. This diminution follows this proportion; as radius to the sine of the complement of the latitude of the place, so are the minutes or miles in a degree of longitude on the equator to those in a degree of the parallel of the given latitude. Thus, for example, to find the length of a degree of longitude on the parallel of London in N. lat. 51° 31′, we add together the sine of 38° 29′ (the complement of that latitude) and the logarithm of 60, the minutes geographical in a degree of the equator; from which sum subtracting the logarithm of radius, we obtain the logarithm of $37\frac{1}{3}$ geographic miles, equal to $43\frac{1}{17}$ English miles, contained in a degree of

longitude at London, and at every other place of the same latitude N. or S. In the same way we find a degree of longitude, on the parallel of Edinburgh, in N. latitude 55° 57′, to contain only $33\frac{3}{5}$ geographic, or $38\frac{3}{4}$ English miles. The most southerly point of Britain is the Lizard in Cornwall, in N. latitude 49° 58′, where a degree of longitude contains $38\frac{3}{5}$ geographic or $44\frac{1}{2}$ English miles. The most northernly point is Dunnet-head in Caithness, in N. latitude 58° 40′, where a degree of longitude contains only $31\frac{1}{5}$ geographic, or $36\frac{2}{3}$ English miles. Hence it appears that, by the convergence of the meridians, on the extent of Britain, of 8° 42′ from S. to N. the difference between the extent of a degree of longitude from E. to W. at the southern, and northern extremities of the island, is $7\frac{2}{5}$ geographic. or $8\frac{1}{2}$ English miles, inducing a very sensible and important departure from parallelism in the direction of the meridians.

From those facts it must follow that plane maps and charts, particularly of tracts at a distance from the equator, on which the degrees and minutes of latitude and longitude are all made equal, must be extremely inaccurate, and consequently must convey very incorrect notions of the relative positions, bearings, and distances of places. To remedy these defects inherent in the construction of plane maps and charts, various attempts have been made: but that which possesses the greatest advantages, and is now universally adopted, was first made known to the world by *Gerard Mercator,* a native of the Netherlands. In 1556, he produced a chart in which the parallelism of the meridians was preserved; but the parallels of latitude were placed at intervals increasing in magnitude as they receded from the equator towards either pole. By this process, the length of a degree of latitude on the map was intended to preserve the same proportion to that of a degree of longitude on the map, the *latter* being always of the same extent, as really happens on the earth where the *former* is always of the same extent. This notion was not however new; for it was hinted at by Ptolemy the great Egyptian astronomer and geographer, in the beginning of the second century of our era. The perfection of the scheme was nevertheless reserved for *Edward Wright* of Caius-college Cambridge, who in 1599, published a work intituled *Correction of certain Errors in Navigation,* containing rules and computations for constructing maps of this sort upon true geometrical principles; of which Mercator himself had, it appeared, been in a great degree ignorant. Wright's book contained tables showing the magnitude of each degree and minute of latitude, in equal divisions called *meridional parts,* now to be found in all treatises on navigation, in which they are of the highest use, and according to which maps and charts are now constructed. These parts are in fact minutes of a degree on the equinoctial. By the convergency of the meridians towards the pole, it was before observed that a degree of longitude at London, or on the parallel of latitude 51° 31′, contained only 37.33 geographic miles: in the same way we find a degree of longitude on the parallel of 50°. lat. to contain 38.57 miles, and one in lat. 51° to contain 37.76 miles. Now if we calculate this case of proportion; as 38.57 the miles in a degree of longitude at latitude 50° to 60 the miles in a degree at the equator, so the same 60 to a 4th number 93.34, miles or meridional corresponding to latitude 50°. In the same way we find 95.34 meridional parts corresponding to latitude 51; and by taking half the sum of these two quantities we obtain 94.34

minutes of the equator for the space to be laid down on the map or chart between the parallels of latitude 50° and 51°; in the tables of meridional parts this space is given, in round numbers, at 95.

The figure 2. plate 1. is a specimen of a map and a sea-chart combined together, containing the eastern provinces of England, as far north as York, constructed on Mercator's, or more properly Wright's principles of projection. The draught being intended to comprehend from the 50th to the 54th degree of N. latitude, and from the second degree of longitude E. from our first meridian, that of Greenwich observatory, to the second degree of W. longitude, it will contain four degrees in both senses: but in consequence of what has just been said, the latitude will occupy much more space on the paper than the longitude. The draught is constructed in this manner. At the bottom of the paper draw a right line to represent the parallel of the 50th degree of N. latitude. On the middle of it erect a perpendicular for the first meridian, distinguished by the cypher O; and on each side of it set off 2 equal parts of the scale adapted to the size of the draught, numbered 1° and 2° E. long. and 1° and 2° W. long. through which points draw lines parallel to the first meridian to represent the meridians passing over those degrees of longitude. Now by calculation as before shown, or from printed tables of meridional parts, find the difference between those corresponding to latitude 50°, and 51°, which was found to be 94.34, or in round numbers 95 minutes of an equatorial degree. Taking this quantity from the same scale with the degrees of longitude, set it up on the two extreme meridians 2° E. and 2° W. from latitude 50° to 51°, and draw the horizontal line for the parallel of N. latitude 51°, as in the sketch. Again, with 191 minutes, the difference between the meridional parts for latitude 50° and 52°, fix points on the two extreme meridians, through which draw the parallel of 52°; and in the same way those of 53° and 54° of N. latitude; which last completes the draught, now divided by the cross meridians and parallels into spaces representing the surface of a degree in latitude and longitude. But as these spaces are too large for laying down places or coasts with accuracy, the parallels at the top and the bottom are subdivided into four equal parts, each consequently representing $\frac{1}{4}$ of a degree, or fifteen minutes. The degrees of latitude are also subdivided into four parts, not equally but by taking the difference between the meridional parts corresponding to the several quarters of degrees. Thus the difference between those for 50° and 50° 15′ is about 23;---50° 30′ is nearly 24, and 50° 45′ is 24, which quantities set up together at each end from 50° will give the divisions of the degree from 50 to 51°. These divisions are merely marked on the margin of the map or chart, it not being usual to draw any lines across the map except those passing through whole degrees. Double lines being drawn on the external meridians and parallels, the small divisions are alternately shaded black, to enable the eye the more readily to distinguish and reckon them.

The skeleton of the map or chart is now ready to receive the places, rivers, coasts, &c. intended to be laid down in this way. The meridian in the middle marked O being that of Greenwich observatory, its place (distinguished by a small circle of which the centre is supposed to be the true position of the observatory,) must be on that meridian. But its latitude being 51° 28′ 40″, lay a ruler from the corresponding points on the perpendicular margins of the map, and mark the

spot where it crosses the first meridian, which will be the position of the observatory. Again, the latitude and longitude of London being computed from the centre of the dome of St. Paul's Church, in latitude 51° 30′ 49″, and longitude 5′ 47″ W. from Greenwich, the circle indicating that position must be placed proportionally to the N. and W. of Greenwich. In the same way, pencil lines drawn across the draught, through latitude 51° 7′ 48″ and E. longitude, 1° 9′ 7″, will by their intersection, show the position of the great tower of Dover castle. The meridian of E. longitude 1 degree 44 minutes 22 seconds will, by the intersection of the parallel of latitude 52° 36′ 40″, give the situation of the spire of Yarmouth in Norfolk. The point where the meridian of longitude W. 1° 6′ 45″ crosses the parallel of latitude 53° 57′ 45″ indicates the place of the minster or cathedral church of York. In this manner are all the other places, points of the land, &c. laid down, as in the following list of names, of which the initials only are inserted in the draught, proceeding from the top to the bottom, and from the left to the right. Y. York, H. Hull, (or correctly Kingston upon the river Hull, to distinguish it from Kingston upon Thames, 14 miles above London,) S. the Spurn Point on the N. of the mouth of the Humber, L. Lincoln, D. Derby, B. Boston, L. Lynn, Y. Yarmouth, N. Northampton, C. Cambridge, H. Harwich, O. Oxford, L. London, G. Greenwich, F. the N. Foreland on the S. of the mouth of the Thames, S. Salisbury, P. Portsmouth, W. the isle of Wight, B. Beachy-head on the coast of Sussex, and D. Dover. These are all the places in E. England: opposite to Dover is the N. W. corner of F. France, containing C. Calais, B. Boulogne, and D. Dieppe. The courses of the rivers, as that of the Thames, passing by Oxford, London, &c. to the sea, and the line representing the sea-coast, are to be laid down from a careful measurement of the most correct maps and charts.

The characteristic difference between a map and a sea-chart is this, that the map, although in common with the chart it exhibits the line of the coast, is entirely appropriated to representations of the towns, villages, seats, lakes, rivers, marshes, woods, heaths, hills, mountains, and all other objects of note within its limits. The boundaries of the several states, provinces, counties, parishes, &c. are also shown by lines of dots or other marks; and for the more ready tracing of these boundaries a narrow line of colour is drawn along each side of them; the same colour being employed for the whole of one particular district; observing always, that for distinctness sake, the colours on the opposite sides of a boundary should be as strongly contrasted as possible.

In all maps and charts, unless otherwise described, the top of the paper is the N. point, the bottom the S. the right hand the E. and the left hand the W. In charts, however, this general indication is not sufficient, because the accurate distribution of the horizon into the points and parts of the compass is of the most essential use in the practice of navigation. For this reason, a circle of the winds, or a figure of the mariner's compass, is inserted in a convenient or central situation in the sea; divided into the 32 points, each point into four quarters, and the whole circumference into 360 degrees, &c. The lines of direction of the principal points are continued from the centre of the compass over the water only; but interrupted when they meet with the land. Of this compass a sketch is given in the right hand upper corner of the draught, shewing 16 bearings, the N. point distinguished by a cross. It is cus-

tomary in maps, and even in sea-charts, to shade the coast line in the engraving: but as the true position of even the most minute parts of the shore is of the utmost importance to the mariner, all shading, whether in the engraving or by colours, had much better be laid aside, as tending to render the outline of the land indistinct and uncertain. Various marks are employed in charts to indicate circumstances necessary to be known by the seaman: thus an anchor complete indicates a roadstead or proper place of anchorage, as in the Downs, at Spithead, &c.; the setting of currents is pointed out by the head of an arrow; the hour of high water by Roman capital letters, as on a dial-plate; rocks above or under water, shoals, sand-banks, and other dangerous spots, by dots and crosses differently arranged. The variation of the magnetic needle of the compass from the true N. and S. line must also be particularly noted at the place where observations have been made, mentioning also the date of such observations. The usual scale for a sea-chart consists of marine leagues, each containing 3 nautical miles, equal to so many minutes of a degree of a great circle, 60 in one degree. These miles are not, however, to be confounded with the various spaces denominated *miles* in different parts of the world. The English statute mile contains 1760 yards, or 5280 feet; consequently $69\frac{1}{4}$ on an average, are equal to 60 nautical or geographical miles: the Scotch statute mile, containing 1920 ells, or 5956 English feet; $61\frac{1}{4}$ are very nearly equal to a degree. On the other hand, the customary road-mile in various parts of Italy, used also in some maps and charts made in that country, contains only 4875 English feet; consequently 60 nautical minutes or miles, equal to 1 degree of a great circle, will comprehend 75 of such Italian miles, corresponding with the ancient Roman mile, which was composed of 1000 paces, or double steps of an ordinary man walking. Each step was calculated at $2\frac{1}{2}$ Roman feet: consequently the pace or *passus* contained 5 of the same feet; and the Roman mile contained 5000 feet. It was from the Latin words *mille passus*, or in the plural *millia passuum*, one or more thousand paces, that different nations formed the name *mile*; but the Roman foot being a little shorter than the standard English foot, 5000 feet Roman are only 4875 feet English. The customary mile of Germany contains something more than $4\frac{1}{2}$ miles English; consequently about 15 are equal to 1 degree. The customary travelling league in Spain, or an hour's journey at the step of the mule, contains nearly 4 miles English: consequently $17\frac{1}{2}$ of such leagues, or hours, are about equal to 1 degree.

In stating the relation between French linear measures and geographical and English, it will be necessasy to enter into some details. For many years past it has been a favourite object, first with the Academy of Sciences, and afterwards with the Institute of Paris, under the sanction of the government, to obtain a correct notion of the real form and magnitude of our globe. Were the earth a perfect sphere, (which is by no means the case with either the earth or any other body of our system) or were it a solid of any other regular form, by measuring a portion of its surface, we could easily determine the magnitude and the form of the whole. Let an observer measure the meridional altitude of the north pole star, as seen from the royal observatory of Greenwich, to be 51° 28′ 40″: let him proceed due north until the altitude be increased one degree, or to 52° 28′ 40″. Then let the space on the surface of the ground, between the two places of observation, be accurately measured; all proper

corrections being applied for the inequalities of the ground, the unequal attraction of the solid parts of the earth, the variation of the refraction of light, the excentricity of the pole star, &c. The true distance on the surface of the earth thus found will correspond to one degree of a great circle in the heavens, and will therefore bear to the whole circumference of the earth the same proportion that one degree bears to the whole circle of 360 degrees: the distance measured on the ground, therefore, being multiplied by 360, will give the whole circumference of the earth. By a repetition of such operations, especially on a considerable extent on the meridian, the form and magnitude of the earth may be ascertained with great accuracy. An attempt of this sort was long ago made in this country by Norwood, on the distance from London to York, two places differing in latitude 2° 26′ 56″, and in longitude 1° 0′ 58″. But his instruments, and his method of computing the distance, were too imperfect to render his operations of any value. Besides other attempts on more rational principles, the French government sent one company of men, eminent for science and skill, to measure a degree of the meridian in the north of Sweden, at the arctic circle, in lat. $66\frac{1}{2}$°, and another, in conjunction with Spanish geometricians, on a similar business, under the equinoctial line, in the vicinity of Quito, in South America. The most important operations, however, performed for determining the form of the earth, were begun in France in 1740, where a meridian was carefully traced and measured, from Dunkirk in the north, in lat. 51° 2′ 10″, to Perpignan, at the east end of the Pyrenees, in lat. 42° 51′ 53″, being a stretch of 8° 10′ 17″, or $\frac{1}{44}$th. part of the whole circumference of the globe. This meridian was lately extended southwards to Barcelona in Spain, in lat. 41° 23′ 8″; and steps were taken to carry it down the east coast of that country as far as the parallel of Iviza, in lat. 39°; making in all a meridional space of 12 degrees, or $\frac{1}{30}$th part of the earth's circumference. Proceeding upon this measurement, performed by the most able geometers of France, and with the best instruments that France and England could furnish, one-fourth of the circumference would be 5130740 French toises, and consequently one degree would contain very nearly $57008\frac{1}{4}$ toises. The quadrant was divided into 10 millions of equal parts, each being, of course, a little more than half a toise, or 3 feet 0 inches $11\frac{1}{3}$ lines French, corresponding to $39\frac{371}{1000}$ inches English. These parts being destined to serve as the standard of all measurement in France, linear, superficial, and solid, were termed *metres*, from the Greek verb to measure. According to this proportion, a degree of a great circle, passing through the poles of the earth, should contain 69.0433 English statute miles, or 69 miles 0 furlongs 76 yards and 7 inches; a space sensibly less than that formerly estimated, which, however, has been gradually diminished by geographers from $69\frac{1}{2}$ miles to $69\frac{1}{4}$, $69\frac{1}{10}$, &c.

"The length of a pendulum vibrating in a certain given time," says the celebrated astronomer *La Place*, in his Treatise on the System of the World, "and that of a meridian of the earth, are the two principal standards that nature has afforded us to fix the unit of linear measures. The first method, which is of easy execution, has the inconvenience of making the measure of length depend on two elements unconnected with it and with each other, namely, gravitation and time. The second method it was therefore resolved to adopt, which is also of great antiquity. It is, besides, so natural for man to refer measures of distance on

the globe he inhabits to the dimensions of that globe itself; in order that, in moving from one place to another, he may form some judgment of the relation between the space moved over and the entire circumference of the globe. This second method has also this advantage, that measures at sea may be made to correspond with those in the heavens. The navigator has constant occasion to compare the distance he sails with the relative arc of the heavens, formed by his change of place: to establish a perfect uniformity between these spaces is therefore of the highest importance to the mariner, the geographer, and the astronomer." On this subject it may be observed, that it is of little consequence from what original the unit or standard is derived, provided we can with ease and accuracy recur to that original. For whether the standard were at first adjusted according to the supposed circumference of the earth, or to the length of the foot, the arm, &c. of some distinguished personage of antiquity or fable, the facility of comparing other measures with it is the same.

It is allowed that the pendulum affords the readiest mode of recovering the standard if lost: and it might, perhaps, have been as proper for the geometers of France to have fixed on one so simple and accessible as the pendulum, as to seek for an imaginary perfection in copying from a more magnificent original, such as the circumference of the earth. It is, however, to be observed, that the correct determination of the length of a pendulum vibrating in a given time, has always been found an operation of extreme difficulty: so much so, indeed, that we can never depend on any measurement of it that shall be exempt from an error of one ten-thousandth part of the whole length.

It was formerly stated (*mechanics*, pages 8 and 22) that, on account of the earth's not being a perfect sphere, the two poles are nearer to the centre than any points at the equator, or any where between the poles and that line. In consequence of this variation of distance, a body will be more powerfully acted upon by central attraction or gravity at the poles, than if it were at a distance from them: hence, a pendulum of a determinate length will perform its vibrations in less time at the poles, than if it were placed at the equinoctial, or at any intermediate point. From a series of most accurate experiments, conducted by the eminent constructor of time-pieces, *George Graham*, the length of a pendulum vibrating seconds, that is 60 times in a minute, in London, was found to be 39.13 inches, and not 39.2, as is commonly stated. This measurement is nearly a mean between the length deduced from *Borda's* experiments in Paris, and *Whitehurst's*, with Hatton's apparatus, in London, as corrected by Nicholson. According to these experiments, the fall of a heavy body, in the first second of motion, appeared to be 16 feet 1 inch, and one-tenth instead of 16 feet, or 16 feet and 1 inch, as usually supposed.

Prior to the revolution, the linear distances used in France were the short league, containing 2090 toises of 6 French feet, equal to 2.53 English miles; the mean or middle league of 2450 toises, equal to 3 English miles wanting 58 yards; and the great league of 2853 toises, equal to 3.454 English miles. This last league is that employed at sea, corresponding to our nautical league, (of 3 nautical miles) of which 20 are a degree; thus containing 57060 toises, or only 52 toises more than the degree resulting from the measurements already mentioned, made in France. Whenever, therefore, on French maps or charts, marine or

nautical, leagues or miles are mentioned, they are to be understood as precisely equal to our nautical or geographical leagues or miles; each league containing, as above, 3.454, or nearly $3\frac{1}{2}$ English miles, and being the 20th part of a degree. On the post-roads of France, distances are reckoned by *postes*, each supposed to contain 2 leagues. According to an accurate measurement by an odometer, or way-wiser, attached to an English travelling carriage, of various roads in the north and the middle of France, extending in all to 484 leagues, or 242 postes, the whole distances amounted just to 1200 English miles: so that on an average the poste contained only 4.96 English miles. Travellers in those parts of France, therefore, err egregiously in computing the league at 3 miles and the poste at 6, while, in fact, the league is only $2\frac{1}{2}$ miles, and the poste 5 miles at the most. In the districts of the south of France, however, along the Mediterranean, as in Languedoc and Provence, a league much longer than that now mentioned has been in use from a very remote period. Conformably to this practice, a space of 172 leagues, or 86 postes, was found to measure 504 English miles; giving, on an average, 2.93, or nearly 3 English miles to the league, and 5.86, or nearly 6 miles to the poste.

In all sea-charts, whether projected on a plane or on Wright's system, the meridians being all parallel, a line drawn obliquely across them will form equal angles with the whole: this is evident from the nature of parallel lines, explained in the Treatise on *Geometry*. Upon the globe of the earth, however, on which the meridians are in no part parallel, but meet at both extremities in the poles, a very different effect must be produced by right lines falling obliquely upon them. A ship at the equinoctial line sailing due N. would, were there no land or other obstacles, arrive at the N. pole. After which, holding on in the same direction, but under a contrary name, she would be said to run S. to the S. pole, and again stand N. to the point of the equator from which she set out. Again, if, from the same point of the equinoctial, she steer either due E. or due W. she would, by holding on either course, circumnavigate the globe on the equinoctial, and at last return to the point whence she departed. In sailing, therefore, from any point on the surface of the globe, (and not from the equinoctial only) on a course directed to either of the four cardinal points N. E. S. or W. a ship would go completely round the globe, and return infallibly to the place where she began her course.

But is only on these four directions that this would happen. Let us suppose a ship from a point on the equinoctial at the first meridian to sail on a NE. course, or that lying equally distant between N. and E. consequently forming an angle of 45° with the meridian. When the ship arrives at the meridian of a point 1 degree of long. to the E. of the point of departure, she will find her course no longer to form an angle of 45° with it, but one sensibly larger. The ship's course must, therefore, be bent to the northward until she come to an angle of 45°, or point to NE. Standing on in the same course till she gain the meridian of another degree of E. long. she will there again find her course to require another deflection to the northward, to form an angle of 45° with the meridian now come to. In this manner were a ship to sail on a course forming such an angle with the meridian, she would be obliged to change her direction continually and gradually towards the N. by which she would describe a spiral or screw line, constantly approaching the N pole, but without the possibility of ever falling into it. What is here

said of a NE. course holds equally true of every other between due N. or S. and due E. or W.; observing at the same time that the ship's course must undergo a continual deflection from the direction on which she set out, at very short intervals, in order to keep on the same point of the compass. What is here stated, although strictly and geometrically true, can seldom, if ever, be of importance in practical seamanship: charts, therefore, representing such a winding spiral track of a ship, can never be required to supersede the ordinary plane, or Mercator's charts. It is here proper to warn the reader, that Mercator's charts and maps are known by that name only in the northern parts of Europe: in France, Spain, and other southern countries, they are called *spherical* charts and maps.

CHAP. VII.

LETTER-PRESS PRINTING.

LETTER-PRESS PRINTING has been for so many years and so extensively practised in many parts of Europe, particularly in this country, that it has long ceased to excite either admiration or curiosity. The principles of the operation are so obvious, and the execution so easy, that in regarding the whole process of making a book, from the formation of the paper, the types, and the ink, the binding, &c. until it arrive at our hands fit for perusal, we can discover nothing beyond the ordinary application of manual labour, directed to objects which the most common abilities may readily attain. This careless manner of considering the art is the natural effect of the total absence of gratitude for the innumerable benefits we receive from it: and yet, to no one branch of art are we nearly so much indebted as to printing. To the discovery and propagation of letter-press printing may most justly be attributed every improvement in religion and law, in agriculture and manufactures, in arts and sciences, and indeed in every particular by which man is distinguished from the other animals, which has appeared in the world for these last three hundred years. It will, in general, hold true, that wherever the art of printing is the most esteemed and cultivated, there the people have made the greatest progress in knowledge and freedom, religious, political, and moral, and there the faculties of the human frame have been called into the most laudable and beneficial exercise. Of the general truth of this observation, a review of the several states of the world will furnish abundant and satisfactory evidence.

The art of printing is comparatively modern; yet antiquaries are not agreed as to the time when, the place where, and the person by whom, it was first discovered or employed. All, however, seem to concur in dating the invention toward the middle of the fifteenth century, about 1442 or 1444; and in pointing out the banks of the Rhine, in the lower

half of its course, as the scene of its first appearance. Haerlem in Holland ,and Mentz in Germany, seem to have the best claims to the invention of printing; and, by a little discrimination, the claims of each place may, perhaps, be equally valid. *Laurence Coster,* who first produced impressions by printing at Haerlem, appears to have employed only wooden blocks on which were carved the contents of a whole page: but the introduction (and a most important one it was) of moveable types, one for each letter, seems to be due to the joint but later labours of *John Fust* or *Faustus,* and *Peter Schoeffer* of Mentz. Printing was first executed in England in 1474, in the almonry of Westminster abbey, by *John Caxton,* a London mercer, who had resided on the continent for many years as the agent of the mercers' company. His first work here was the *Game at Chess;* and from that time to 1491, when he died, Caxton applied with such ardour to translating and printing, that, though an old man, he published about fifty books, some of them works of considerable size. It is true that a book was printed at Oxford by *Corselis,* a foreigner, bearing for its date 1468: (mcccclxviii) but the best judges of the subject agree in thinking, that by the accidental omission of one x, the printing is antedated ten years, and that the true date was 1478 (mcccclxxviii). There is no certainty of any establishment of a printing press in Scotland before 1507, when *Walter Chapman,* a merchant of Edinburgh, obtained a patent from James IV. for himself and *Andrew Myllar,* to carry on the business of printing.

Although printing be but a modern invention, yet many of the ancients had approached so nearly towards it in various ways, that we wonder how they should have missed it. This, however, is only what happens with respect to many other discoveries, which, when once brought to light, appear so obvious, that we are amazed at their so long remaining unknown. Were we to rest contented (as seems to be the wish and the purpose of many persons charged with the important office of public instruction) with our present version of the sacred writings, the practice of printing might be traced back to a very early period indeed. In the 23d verse of the 19th chapter of the book of Job, that eminent personage is represented, in our common version, as wishing in the fulness of his heart, that his vindication of himself against the revilings of his friends, might be "*printed in a book.*" As this version was executed only about 150 years after the first appearance of printing, it may surprise us that the incongruity of these terms, even if they had seemed to be warranted by the original text, did not strike the learned translators. The whole passage is a singularly eloquent and affecting climax. "Oh that my words were now written down!—that they were recorded in the public register of the land—that they were engraved with a pen of iron on a tablet of lead—even on the rock itself that will never decay!" But to come down to later times. Cicero, who, during the horrible disorders in the Roman state, consequent on the perfidious and most unmerited murder of Julius Cæsar, met with the fate which usually attends disingenuousness, selfishness, and want of resolution in similar circumstances;—Cicero observes in his writings, that the persons who, according to what is called the Epicurean system of philosophy, ascribe the origin of the world to the accidental concourse and arrangement of atoms or imperceptible particles of matter, might just as reasonably conclude that a great number of forms of the letters of the alphabet, made of gold or any other mate-

nals, if jumbled and shaken together and then thrown out on the ground, could by such an accidental distribution, compose the *Annals of Ennius*, or any other literary production. In another passage Cicero speaks of imprinting on wax the notes or marks of alphabetic characters. Quintilian also afterwards mentions forms of the alphabetic characters, made of ivory, put into the hands of children at school, in order to teach them to read. Among the very interesting remains of antiquity discovered in the subterranean town of Herculaneum, overflowed by the lava of Vesuvius, were found some loves of bread, hardened to stone by the heat, with marks of various kinds upon them, which could have been impressed in no other way than as a London baker stamps his W. at present, to certify that it contains the due weight of flour. Roman letters of a different sort were also discovered in the same place cast in bronze, and twenty inches in height. These were fixed in the front of a building, to record its destination, and perhaps the date of its erection and the name of the dedicator. Such an inscription in such a place must have been peculiarly interesting: and it certainly required no common effort of stupidity to deprive the world of the benefit of the discovery. The royal engineer intrusted with the conduct of the antiquarian researches was informed of the discovery, and immediately, as a proof at once of his skill in his business and of his loyalty, commanded the brazen letters to be violently torn from their place, thrown pell-mell into a basket, and hastened to lay them in this instructive state at the feet of his royal master. Had a copy of the inscription been taken, while the letters were in their place, curiosity might have been satisfied; or even had the stones on which they were fixed been suffered to remain undisturbed or undefaced, the inscription might, with the aid of the letters, and of the holes by which they were fastened, have been correctly made out. A much more difficult task was performed by *M. Seguier*, in making out the inscription on the frontispiece of the celebrated *Maison carrée* of Nismes in the south of France, a structure erected to the honour of Caius and Lucius, the grandsons of Augustus Cæsar by Julia his daughter married to Agrippa. For here the letters were entirely gone, and nothing remained but the nails by which the letters, probably of bronze, were secured. It is true indeed, that the south of Italy, in knowledge, ingenuity and taste, is centuries behind the south of France, and destined probably long so to remain.

Paper. In order to form some general notion of printing, it will be necessary to say a few words on the nature of the materials, and implements employed in the operation, viz. paper, ink, types, and the printing-press. Paper is supposed to draw its name from the *papyros*, as the Greeks called it, a kind of large rush growing in the marshes of the Nile in Egypt. The stalk is triangular, terminating in a large heavy bearded head. The interior of the lower part of the stalk is eaten by the people of the country. A plant of the same kind, still called *papero*, is found in stagnating waters near Syracuse in Sicily, believed to have been carried thither from Egypt. The inner part of the bark of the plant was employed by the ancients in the fabric of paper. Strips of this bark were laid on a table, with others across them, and the whole, by means of water and some cohesive substance, was strongly pressed together, until it combined into one compact body. Hence it is that in ancient authors mention is made of paper of different layers or courses of the bark. Of the first use of the papyrus as a material to

be written upon we know no more than that Herodotus, who wrote four hundred and fifty years before our era, states that, in times which he thought ancient, both paper and skins of animals were in common use for writing. The reference made by Job to writing has already been mentioned; and whatever date may be allotted to his existence, or to the composition of his history, the best judges of the language in which it is composed consider it to be coeval with Moses, who flourished above a thousand years before Herodotus. The use of the Egyptian papyrus seems to have been known even in the days of Homer, nine hundred years before our era; but it was not until the time of Alexander, six centuries later, that it came to be prepared in due perfection. Not only paper, but the papyrus rush itself was carried from Egypt to Rome, where it was converted into paper. It varied, as we learn from Pliny, who wrote towards the end of the first century, in its qualities and breadth from the *Emporetica*, so called because employed to wrap up commodities for sale, six inches in breadth, to the higher sorts the *Augusta*, the *Liviana*, and the *Hieratica*, which were thirteen inches broad. The Augusta paper proving too transparent, a paper of a thicker quality, and eighteen inches broad was introduced under Claudius, and from him called Claudia. Each sheet of the ancient paper at Rome was double, the principal side being the largest slice that could be got, of uniform breadth, in the whole length of the papyrus; and it was covered or lined with shorter pieces fastened on with the glutinous water of the Nile or with paste. The longitudinal fibres of the plant, running thus across one another, gave the paper the appearance of linen. A specimen of papyrus paper in the British Museum London is about nine feet long by twelve or thirteen inches broad. On it is written a donation by a pious lady, dated in the 27th year of the emperor Justinian, or in our year 553.

After the Saracens, (so called by their suffering neighbours, from an Arabic term still retained in Malta signifying thieves or robbers,) had obtained possession of Egypt, all intercourse of the Christians with that country was cut off, until the beginning of the ninth century. Hence it happens that the writings of importance in Europe which, before the Saracen invasion, had been done on papyrus, are afterwards always written on parchment. In the middle of the tenth century we are told by an Arabian traveller, that the best paper in the world was made at Samarcand in the heart of Asia; but the nature of this paper is not mentioned. About the year 1100, and perhaps long before, paper made of cotton was used for books and other writings. A charter dated in 1102, is described as written on cotton paper *(charta cuttunea,)* in a renewal of it by Roger king of Sicily in 1145. This kind of paper was also called *charta bombycina*, signifying properly paper made of silk, but extended also to cotton which, even in the present day, is called *bambaccia* by the Italians: hence we have the stuff called *bombazine*, and *bastine*, now corrupted into *fustian*. This cotton paper, become common in the Eastern empire, in a great measure superseded, or rather made up for the want of the Egyptian papyrus and parchment. It is probably to the discovery of cotton paper that we owe the preservation of such of the writings of the authors of ancient Greece and Rome, as have come down to our times; as the scarcity and high price of parchment had occasioned the destruction of many of those writings. For the monks who were almost the only readers, writers,

and librarians of the dark ages, made no conscience of erasing the writings of the most valuable classic authors, in order to procure a piece of parchment fit to record the more precious lives and miracles of his favourite saints. And it is not less curious than just, that the care taken to preserve those monkish records has been in its turn the means of preserving, and restoring to the world, many valuable fragments of the ancients with which the parchment had been originally covered. Cotton paper was not however found sufficiently stout and durable for important purposes; on which account the emperor of Germany Frederic II. in 1221, ordered all public deeds and securities to be written thenceforth on parchment alone. Meerman, chief magistrate of Rotterdam in Holland, after very laborious study and research, fixed the beginning of the manufacture of paper from linen rags, between the years 1270 and 1302. And in the Transactions of the Society of Antiquaries of London, Vol. V. act. 10, mention is made of a letter existing in the Tower, from a king of Spain to Edward I. written in 1272 on paper: but the substance of the paper is not stated. The most ancient specimen of paper such as we now use, made of linen rags, is a charter seven inches long, and three inches broad, preserved in the Emperor's library in Vienna, which was written in the year 1243; being at least half a century older than any other specimens of which the date and the existence are well known. Among the articles composing the cargo of a Spanish ship from Genoa for Sluys, the port of Bruges, in Flanders, wrecked on the west coast of England in 1380, are mentioned 22 bales of writing paper. Of late times much of the paper used in Italy is, on the contrary, drawn from Flanders. Parchment, a corruption of the French *parchemin*, is a preparation of sheep and other skins, for the purposes of writing and printing, so called, as it is commonly said, from *Pergamus*, the capital of a kingdom on the western coast of Asia Minor, who devised that substitute for Egyptian paper, of which the exportation had been prohibited. That animal skins were, however, used long before this period, is not to be doubted: material improvements may, notwithstanding, have been introduced at Pergamus, sufficient to warrant the adoption of that particular name.

Chinese paper, so remarkable for its peculiar delicacy, is of various sorts. Some is made of the rind or bark of trees, especially of the mulberry and the elm, or else of the bamboo and cotton tree. Each different province of that immense empire may, indeed, be said to make its own peculiar sort of paper. That of the bamboo, a species of the cane or reed, is made from the second bark, which is soft and white. It is beaten in fair water to a pulp, which is taken up in moulds of such a size, that sheets are sometimes made of twelve feet in length. These are afterterwards dipped in alum-water, which renders the paper impenetrable by ink, and gives the paper the appearance of being varnished. It is white, soft, and of a close texture; but although quite smooth, it breaks more easily than European paper: it is also so thin as to be soon worn out, and is, besides, very subject to destruction by worms.

The inventor of paper made from linen rags, whoever he was, is entitled to the sincerest gratitude of the world and of posterity. The art of printing would be comparatively but of little importance, unless we had such a material as linen-paper to receive the impressions. While the papyrus was alone used, it was impossible to procure it in sufficient quantity to satisfy the demands of many readers. The cotton-paper was

but a rude and coarse material, unfit for any of the delicate purposes to which linen-paper is applicable. The perfection of the art of paper-making, therefore, consisted in finding a substance which could be procured in sufficient quantities, would be of easy preparation, and applicable to every purpose: such is the paper now in use. A more common, or less valuable substance cannot be conceived, than the remnants and fragments of our garments, our linen worn out, and otherwise incapable of being turned into use, and of which an abundant supply is continually furnished. Nor can a labour more simple be conceived than trituration, for a few hours, in water by a mill. So great is the dispatch in preparing the material by the mill, that five workmen may furnish paper sufficient to occupy three thousand writers and transcribers; and this even on the old plan of hand labour: but by the modern improvements of mills, where the paper is produced in one continued web, instead of sheet by sheet, a great portion of the labour is totally done away.

The operations of paper-making, in their regular order, are these: 1st, The linen rags are washed and sorted. 2d, They are bleached to whiten them: but this operation is sometimes deferred to a later period. 3d, They are ground in water in the washing engine, till they are reduced to a coarse or imperfect pulp, called in the business *half-stuff*, in which state the bleaching is sometimes performed. 4th, The half-stuff is again ground in the beating engine, and water is added in quantity sufficient to make a fine pulp. 5th, This last being conveyed to the vats, the sheets of paper are made by taking up a quantity of the pulp upon a mould of fine wire-cloth, through which the water drains away, leaving upon the wire the pulp, which consolidates into what we call a sheet of paper: the operation of taking off this sheet is termed *couching*. 6th, These sheets are piled up with a felt of wool or hair between each two; and the whole are then strongly pressed, to force off the water. 7th, The sheets are then taken out, the felts removed, and the sheets are pressed again by themselves, for a certain time. 8th, The sheets are taken out from the press and hung up, five or six together, to dry in the drying-loft. 9th, The paper is dipped into a vessel containing fine size, and again pressed, to remove the superfluity, after which it is again dried: but in printing paper this process is rendered unnecessary, by sizing the stuff itself whilst in the engine. 10th, The paper now undergoes an examination of each individual sheet; all knots and burs are removed, and bad sheets are taken out. 11th, The dry sheets are packed in a very large pile, and pressed with a prodigious force, to render them flat and smooth. 12th, The paper is taken out, parted, and again pressed. *Parting* is the taking down of the pile, sheet by sheet, and making another pile, without turning over the sheets. By this management new surfaces are brought into mutual contact, and the face of the paper is improved. 13th, The paper is now finished, counted out in *quires*, folded, and packed in *reams* for sale.

The linen rags used in making paper are purchased by dealers, who separate them into five sorts of white rags for the mills, entitled Nos. 1, 2, 3, 4, and 5, according to their fineness; No. 1 being all linen, the remains of fine cloth, is used for making the finest paper; and No. 5, consisting of coarse canvas, may be bleached, but makes only coarse paper. The first three sorts are for writing and fine printing; the remainder for news-papers, and other inferior papers. Old paper may be used for the same pur-

poses: but the waste would be too considerable, on which account it is generally reserved for pasteboard.

The greatest care ought to be used in sorting and separating the rags of different qualities, otherwise the necessary reduction to pulp, the bleaching, &c. will be unequally done, and the inequality of the paper will occasion a loss more than equivalent to the additional expence of particular sorting.

The greatest improvement in modern paper making is in the bleaching of the rags. This enables the manufacturer to produce the finest paper, in point of colour, from almost any kind of rags. This business is thus reduced to find materials fit to make a paper of a strong texture, and a fine even surface; knowing he can in the bleaching produce any colour he may wish for. The bleaching of the rags is conducted much in the same way with that of cotton thread, by means of the vapour or gas produced from manganese, salt, and sulphuric acid.

We shall now rever to the original object of this essay, the art of printing. The workmen employed in this art are of two kinds: compositors, who arrange and dispose the letters according to the copy delivered them by the author; and pressmen, who apply the ink and take off the impression. The types being cast, the compositor distributes each kind by itself, among the divisions of two wooden frames, an upper and an under one, called cases, each of which is divided into little cells or boxes. Those of the upper case are in number 98, all of the same size, and in them are disposed the capitals, small capitals, accented letters, figures, &c. the capitals being placed in alphabetical order. In the cells of the lower case, which are 54, are placed the small letters, with the points, spaces, &c. The boxes are here of different sizes, the largest being for the letters most used; and these boxes are not in alphabetical order, but the cells which contain the letters oftenest wanted are nearest the compositor's hand. Each case is placed a little aslope, that the compositor may more easily reach the upper boxes. The instrument in which the letters are set is called a composing stick, which consists of a long and narrow plate of brass or iron, on the right side of which, arises a ledge which runs the whole length of the plate, and serves to sustain the letters, the sides of which are to rest against it. Along this ledge is a row of holes, which serve for introducing a screw, in order to lengthen or shorten the extent of the line by moving the slider further from, or nearer to the short ledge at the end.

Before the compositor proceeds to compose, he puts a rule, or thin slip of brass plate cut to the length of the line, and of the same height as the letter, in the composing stick, against the ledge, for the letter to bear against. Things thus prepared, the compositor having the copy lying before him, and his stick in his left hand, his thumb being over the slider, with the right he takes up the letters, spaces, &c. one by one, and places them against the rule, while he supports them with his left thumb, by pressing them to the end of the slider; the other hand being constantly employed in setting in more letters: the whole being performed with a degree of expedition and address not easy to be imagined.

A line being thus composed, if it ends with a word or syllable, and exactly fills the measure, there needs no further care. Otherwise spaces are to be put in, or else the distances lessened between the several words, in order to make the measure quite full; so that every line may

end even." The spaces here used are pieces of metal exactly shaped like the shanks of the letters; these are of various thicknesses, and serve to support the letters, and to preserve a proper distance between the words, but not reaching so high as the letters, they make no impression when the work is printed. The first line being thus finished, the compositor proceeds to the next, in order to which he removes the brass rule from behind the former, and places it before it, and thus composes another line against it, after the same manner as before; going on thus till his stick is full, when he empties all the lines contained in it into the galley, which is a frame formed of an oblong square board, with a ledge on three sides, and a groove to admit a false bottom. The compositor then fills and empties his composing stick as before, till a complete page is formed, when he ties it up with a cord or pack thread, and setting it by, proceeds to the next, till the number of pages contained in a sheet is completed: which done, he carries them to the imposing stone, there to be ranged in order, and fastened together in a frame called a chase, and this is termed imposing. The chase is a rectangular iron frame, of different dimensions according to the size of the paper to be printed; having two cross pieces of the same metal, called a long and short cross, marked at each end, so as to be taken out occasionally. By the different situations of these crosses, the chase is fitted for different volumes. For quartos and octavos, one traverses the middle lengthwise, the other breadthwise, so as to intersect each other in the centre; for twelves, and twentyfours, the short cross is shifted nearer to one end of the chase; for folios the long cross is left entirely out, and the short one left in the middle; and for broadsides both crosses are laid aside. To dress the chase, or arrange and fix the pages therein, the compositor makes use of a set of furniture, consisting of slips of wood of different dimensions, and about half an inch high, that they may be lower than the letters. Some of these are placed at the top of the pages, and called head-sticks; others between them, to form the inner margin; others on the sides of the crosses, to form the outer margin where the paper is to be doubled, and others in the form of wedges to the sides and bottom of the pages. Then all the pages being placed at their proper distances, and secured from injury by the chase, and the furniture placed about them, they are all untied, and fastened together by small pieces of wood called quoins, cut in the wedge form, up between the slanting side of the foot and side sticks, and the chase, by means of a piece of hard wood and a mallet. All being thus bound fast together, so that none of the letters will fall out, it is ready to be committed to the pressmen. In this condition the work is called a form, and as there are two of these forms required for every sheet when both sides are printed, it is necessary that the distance between the pages in each form should be placed with much exactness, that the impression of the pages in one form shall fall exactly on the back of the pages of the other, a process which is called register.

The forms being sent to press, a proof is taken and examined by the readers, and the compositor rectifies the mistakes by picking out the faulty or wrong letters, with a slender sharp pointed steel bodkin, and puts others into their places; but when there are considerable alterations, and particularly where insertions or omissions are to be made, he is under the necessity of *over-running*, or re-arranging many lines in succession.

The business of the pressmen is to work off the forms thus prepared and corrected by the compositor: in doing which there are four things required: paper, ink, balls, and a press. The printing press of the common construction, and of Lord Stanhope, are too familiar to every person to require description. To prepare the paper for use, it is first wetted by dipping several sheets together in water; these are afterwards laid in a heap over each other, and to make them take the water equally, they are all pressed close down with a weight at the top. The ink is a composition of lamp black and linseed or suet oil, boiled so as to acquire considerable consistence and tenacity. The art of preparing it is kept a secret, but its excellence depends almost exclusively on the goodness of the lamp black.

Stereotype printing was introduced into this country by Mr. Ged of Edinburgh, was adopted by the university of Edinburgh, and has been extended with much success by Messrs. Watts, Wilson, Brightly, and Cock and M'Gowan. The mode of stereotype printing is first to set up a page in the common way, and when it is rendered perfectly correct, a cast is taken from it, and in this cast the metal for the stereotype plate is poured. For standard and extensively circulating works, the invention is invaluable, as the chief expence of future editions is completely obviated, and the original types, after the cast is made, may be devoted to their former use. The printed paper is now consigned to the book-binder, who first folds the sheets with a folding stick, and lays them over each other in the order of the signatures, which are the letters with the numbers annexed to them at the bottom of the pages of the first one, two, or more leaves in each sheet. The leaves thus folded are then beaten on a stone with a hammer, to make them smooth, and open well, and afterwards pressed. While in the press they are sewed upon bands, which are pieces of cord or pack thread; six bands to a folio book, five to a quarto, octavo, &c. which is done by drawing a thread through the middle of each sheet, and giving it a turn round each band, beginning with the first, and proceeding to the last. After this the books are glued, and the bands opened and scraped for the better fixing the pasteboards; the back is turned with a hammer, and the book fixed in a press between two boards, in order to make a groove for fixing the pasteboards. These being applied, holes are made for fixing them to the book, which is pressed a third time. Then the book is at last put to the cutting press, betwixt two boards, the one lying even with the press, for the knife to run upon, the other above it for the knife to run against; after which the pasteboards are squared.

The next operation is sprinkling the leaves of the book, which is done by dipping a brush into vermilion and sap-green, holding the brush in one hand, and spreading the hair with the other; by which motion the edges of the leaves are sprinkled in a regular manner, without any spots being larger than the rest.

The covers, which are either of calf or sheep skin, being moistened in water, are next cut out to the size of the book, then smeared over with paste made of wheat flour, and afterwards stretched over the pasteboard on the outside, and doubled over the edges withinside, after having first taken off and indented, and platted the cover at the head-band; which done, the book is covered, and bound firmly with bands, and then set to dry. Afterwards it is washed over with a little paste and water, and then finely sprinkled with a brush; unless it

should be marbled, when the spots are to be made larger by mixing the ink with vitriol. After this, the book is glued here with the white of an egg beaten, and at last polished with a polishing iron passed hot over the glazed cover.

The letters or other ornaments on books, are made with gilding tools engraved in relievo, either on the points of puncheons or around little cylinders of brass. The puncheons make their impressions by being pressed flat down, and the cylinders by being rolled along by a handle, to which they are fitted on an iron axis. To apply the gold, the binders glue the parts of the leather with liquor made of the whites of eggs diluted with water, by means of a piece of spunge, and when nearly dry, the pieces of gold leaf are laid on; the tools being made hot in a charcoal fire, are also laid on, and the book is finished.

CHAP. VIII.

GALVANISM.

Galvanism is a term used to denote the influence of metals by mere external contact with the animal body. Its operation was first discovered by Dr. Galvani of Bologna, who announced it to the scientific world in a publication entitled Commentaries on the Powers of Electricity on Muscular Motion. The discoveries of Galvani were made principally with dead frogs: he in the first place discovered that a frog, dead and skinned, is capable of having its muscles brought into action, by means of electricity, however small its quantity. Secondly, that independent of any apparent electricity, the same motions may be produced in the dead animal, or even in a detached limb, merely by making a communication between the nerves and the muscles, with substances that are conductors of electricity. If the circuit of communication consists of non-conductors of electricity, as glass, sealing wax, and the like, no motion will take place. Similar experiments were successfully instituted on other animals; and as the power seemed to be inherent in the animal parts, those experiments, or the power which produces the motion of the muscle in these experiments, were denominated animal electricity. But it being now fully ascertained, that by the mere contact of metallic, and other conducting substances, some electricity is generated, it is evident, that the muscular motions in the above experiments are produced by metallic electricity.

It had been long asserted, that when porter is drank out of a pewter pot, it has a peculiar taste different from that which arises when drank out of a glass, or earthen ware; and when the copper sheathing of ships is fastened on by means of iron nails, the metallic electricity is evinced in the corrosion of those nails about the place of contact. Pure mercury retains its metallic splendour for a long time, but its amalgam with any other metal is soon tarnished or oxydated. The Etruscan inscriptions engraven on pure lead are preserved to this day, whereas some medals of lead or tin of no very ancient date, are much corroded. Works of metal whose parts are soldered together by means of other metals, soon

tarnish about the places where the different metals are joined. A piece of zinc might be kept in water for a considerable time without oxydation; but that circumstance would soon take place if a piece of silver happened to touch the zinc while standing in water. All these circumstances agree with the hypothesis, that the contact of different metals, acted upon by an intermediate fluid, or the intervention of a metal between two different fluids, will produce the phenomena of galvanism.

The conductors of electricity, which all differ from each other considerably in conducting power, may be divided into two classes. The first class, called also dry and perfect conductors, consists of the metallic substances and charcoal. The second class, or the imperfect conductors, are water and the oxydating fluids, such as acids, as also the substances which contain those fluids. The substances of the second class differ in conducting power much more than those of the first class.

The simplest combinations capable of exciting galvanic electricity, must consist of three different conductors; for two conductors only will not produce any sensible effect. If the three conductors be all of the first class, or all of the second, then the effect is seldom perceivable. To make the combination active, it must consist of three different bodies, viz. of one conductor of one class, and two different conductors of the other class.

When two of these bodies are of the first class, and one is of the second, the combination is said to be of the first order; otherwise it is said to be of the second order.

In a single active galvanic combination, or, as it is commonly called, a simple galvanic circle, the two bodies of the same class must touch each other in one or more points, at the same time that they are connected with each other at other points, by the third body of the other class.

The nerves of animals appear to be affected by smaller quantities of electricity than any other substances with which we are acquainted: hence prepared limbs of animals are much employed for ascertaining the production of electricity by simple contact, or galvanic electricity.

The sensibility of the prepared animal is greatest at first, but it diminishes by degrees, till it vanishes entirely. Cold-blooded animals, especially frogs, retain this sensibility for several hours, sometimes even for a day or two. With other animals the sensibility does not last long after death, and sometimes not above a few minutes. Galvani first discovered that a frog, dead and skinned, is capable of having its muscles brought into action by means of common electricity, even in exceeding small quantities, probably by one-hundredth part of what would just affect a very delicate electrometer.

If the leg of a frog recently dead, be separated from the rest of the body, but having a small portion of the spine attached to it, and if it be so situated, that a little electricity may pass through it, either by the immediate contact of an electrified body, or by the action of electrified atmospheres (as when the preparation is placed within a certain distance of an electrical machine, and a spark is taken from the prime conductor), the legs of the animal will be instantly affected with a kind of spasmodic contraction, sometimes so strong as to jump a considerable way.

If the electricity be made to pass through the prepared limb by the

immediate contact of the electrified body, a much smaller quantity of it is sufficient to occasion the convulsive movements, than when it is made to pass from one conductor to another, at a certain distance from the prepared limb: and these movements are much stronger when the electricity passes through a nerve to the muscles, than through any other part.

Galvani afterwards discovered, that similar effects may be produced in the prepared animal, without the apparent aid of electricity, by only making a communication between the nerves and the muscles by a conducting substance.

In an animal recently dead, detach one end of a nerve from the surrounding parts, taking care not to cut it too near its insertion into the muscle: remove the integuments from over the muscles which depend on that nerve: take a piece of metal, as a wire, touch the nerve with one extremity of it, and the muscles with the other extremity: on doing which, you will find that the prepared limbs are affected in the same manner as when electricity is passed through them.

If the communication between the nerve and the muscle be formed by substances which are non-conductors of electricity, such as glass, sealing-wax, &c. then no movements will take place.

The communication between the muscle and the nerve may consist of one or more pieces, and these may be of the same conducting substance, or, what is better, of different substances connected together. The bodies which answer best for this purpose are silver and zinc; but silver and tin, copper and zinc, and other combinations, are nearly as good. If part of the nerve of a prepared limb be wrapped up in a bit of tin-foil, or be only laid upon zinc, and a piece of silver be laid with one end upon the muscle, and with the other upon the above mentioned tin or zinc, the motion of the limb will be very violent.

The two metals may be placed either in contact with the preparation, or in any other part of the circuit, which may be completed by means of other conductors, as water, &c. Place two wine-glasses, full of water, near each other, but not actually touching. Put the prepared thigh and leg of a frog into the water of one glass, and laying the nerve over the edges of the two glasses, and let the tin-foil which is wrapped round it, touch the water of the other glass. If now you form the communication between the water in the two glasses, by means of silver, or put the fingers of one hand into the water of the glass that contains the leg, and holding a piece of silver in the other, you touch the coating of the nerves with it, you will find that the prepared legs are so violently excited, as sometimes actually to jump out of the glass.

These convulsive motions may be excited not only in dead, but also in living animals, particularly of the cold-blooded kind, as frogs, eels, flounders, &c. Place a living frog upon a plate of zinc, having pasted a slip of tin-foil upon its back; then form a communication between the zinc and the tin-foil, by means of a wire or other piece of metal, and the same kind of contractions will take place in the limbs, as are excited in the prepared limbs of dead animals by the same means. This experiment may even be performed, if the frog be entirely under the water.

A flounder may be acted upon in a similar manner. Take a live flounder; dry it with a cloth, and put it in a pewter plate, or upon a large piece of tin-foil, and place a piece of silver upon its back. Then

with one end of a piece of metal touch the pewter plate, and apply the other extremity of the metal to the piece of silver, and contractions will immediately ensue.

All animals, whether large or small, may be affected in the same manner by galvanism, but in different degrees.

The limbs of men, while undergoing the operation of amputation, have been convulsed by the application of metals.

Both the senses of taste and sight are also capable of being affected by it. Let a man lay a piece of metal upon his tongue, and a piece of some other metal under the tongue: on forming a connection between those two metals, either by bringing their outer edges in contact, or by the interposition of some other piece of metal, he will perceive a peculiar sensation, a kind of irritation, accompanied by a cool acid taste, much resembling that produced by common electricity applied to the tongue.

In order to affect the sense of sight by means of metals, let a man put a piece of zinc or tin between the upper lip and the gums, as high as possible, and a piece of silver upon the tongue; whenever the two metals are made to communicate, either by touching, or by the interposition of another piece, a flash of light will be instantly perceived.

The most powerful galvanic circles of the first order are, where two solids of different degrees of oxydability, are combined with a fluid capable of oxydating at least one of the solids. Thus gold, silver, and water, do not form an active galvanic circle; but the circle will become active, if a little nitric acid, or any fluid decomposible by silver, be mixed with the water. An active galvanic circle is formed of zinc, silver, and water; and the zinc is oxydated by the water, provided the latter contains some common air, as it generally does, and still more, if it contain oxygen air. But a little nitric acid added to the water, renders the combination more active, as the acid acts both upon the zinc and the silver.

The most powerful galvanic combinations of the second order are, where two conductors of the second class have different chemical actions on the conductors of the first class, at the same time that they act upon each other. Thus copper, silver, or lead, with a solution of an alkaline sulphuret and diluted nitrous acid, form a very active galvanic circle.

The following tables of galvanic arrangements were composed by Sir H. Davy, professor of chemistry at the Royal Institution:

Table of Galvanic Circles of the First Order, composed of two perfect Conductors, and one imperfect Conductor

Very oxydable substances.	Less oxydable substances.	Oxydating fluids.
Zinc	With gold, charcoal, silver, copper, tin, iron, mercury.	Solutions of nitric acid in water, of muriatic acid, and sulphuric acid, &c. Water holding in solution oxygene, atmospheric air, &c.
Iron	With gold, charcoal, silver, copper, tin.	
Tin	With gold, silver, charcoal.	
Lead	With gold, silver.	

Very oxydable substances.	Less oxydable substances.	Oxydating fluids.
Copper	With gold, silver.	Solution of nitrate of silver and mercury, nitric acid, acetous acid.
Silver	With gold.	Nitric acid.

Table of Galvanic Circles of the Second Order, composed of two imperfect Conductors, and one perfect Conductor.

Perfect Conductors.	Imperfect Conductors.	Imperfect Conductors.
Charcoal Copper Silver Lead Tin Iron Zinc	Solutions of hydrogenated alkaline sulphurets capable of acting on the first three metals, but not on the last three.	Solutions of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.

The action of a simple galvanic circle seems to be in some measure dependent upon the quantity of surface of contact between the acting bodies; and a higher temperature, within certain limits, renders the activity of the circle greater than a lower temperature.

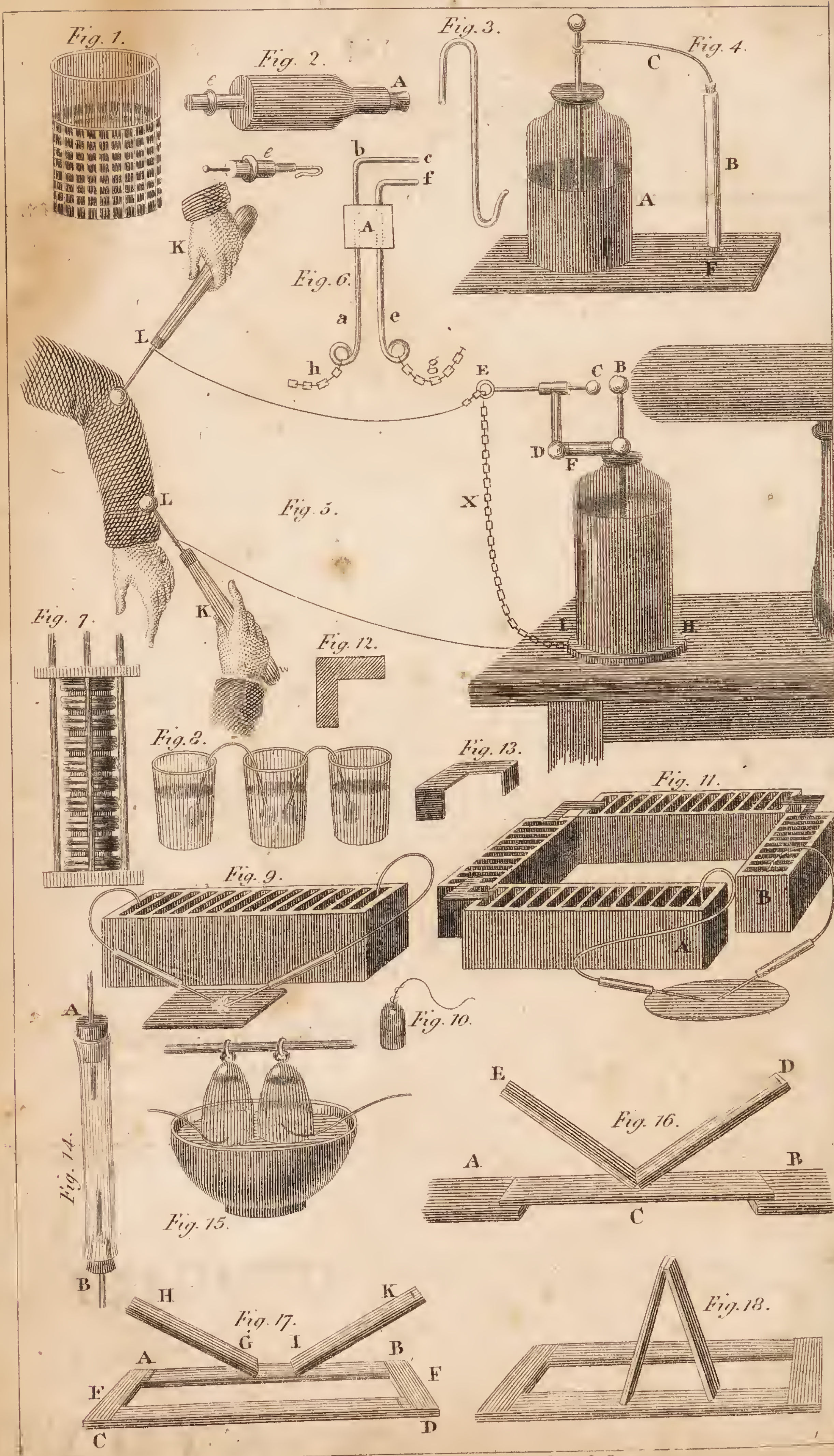
Since Galvani's discoveries, the action arising from the combination of three conductors has been examined with great care and with considerable success, by Mr. Volta, who discovered, a few years ago, that the slight effect of such a combination may be increased prodigiously by repeating the combination: for instance, if a combination of silver, zinc, and water, produce a certain effect, a second combination (viz. another piece of silver, another piece of zinc, and another quantity of water) added to the first, will increase the effect: the addition of a third combination will increase the effect still more, and so on.

These repeated combinations are now called galvanic piles, or batteries, though in justice they ought to be called Volta's batteries.

These batteries are said to be of the first or second order, according as the simple combinations of which they consist are of the first or second order. Thus, if a piece of zinc be laid upon a piece of copper, and a piece of moistened card be laid upon the zinc; then a similar arrangement of three other such pieces be laid upon them, and a third arrangement be laid upon that, &c. all in the same order, the whole will form a battery of the first order. But if the arrangement be made by connecting a piece of copper with a piece of cloth moistened with a solution of sulphuret of pot-ash, and this, again, with another piece of copper, &c. the whole will form a battery of the second order.

Care must be taken in arranging the pieces of a galvanic battery, that the parts do not counteract each other. The method of doing this will be easily understood, when it is considered that every simple galvanic combination has a positive and negative end; or that, in every complete galvanic circle, the electric fluid circulates in one way only. Thus if two simple combinations are so arranged, that the two currents oppose each other, they will be both annihilated, if equal; or, if unequal, the effect will be only the excess of one above the other.

GALVANISM.



Pub. by T. Kinnersley, Novr. 30, 1816.

These batteries may be constructed in an infinite variety of forms. We shall describe those that have been as yet most generally used.

The apparatus of Volta was constructed in the following manner: Take a number of plates of copper, or, what is better, of silver, and an equal number of tin plates, or, what is still better, of zinc, and the same number of pieces of card, leather, or woollen cloth, the last of which seems to answer the best. Let these last be well soaked in common water, or rather in a solution of common salt, sal ammoniac, nitre, or nitrous acid. The silver, or copper, may be pieces of money, and the zinc pieces may be cast of the same size. A pile is to be formed of these substances in the following manner: a piece of zinc, a piece of silver, and a piece of wet cloth, or card; then another piece of zinc, a piece of silver, and a piece of wet cloth; and so on in the same order, till the number required has been placed. The instrument is then fit for use; but as the pieces, when unsupported, are apt to fall down when their number is considerable, it is best to support them by means of three rods of glass, stuck into a piece of wood, and touching the metallic pieces at three equally distant points, as represented in Fig. 7. Down these rods may slide a small circular piece of wood, having three holes in it, and which will serve to keep the top of the pile tight, and the different pieces in close contact. The moistened pieces should likewise be somewhat less than the pieces of metal, and though they should be well moistened, they should be gently squeezed before they are applied, that the superfluous moisture may not run down the pile, or insinuate itself between the pieces of metal.

The instrument, constructed in this manner, will afford a perpetual current of the electric fluid, through any conductor communicating between the uppermost and lowest plate: and if one hand be applied to the lowest plate, and the other to the upper, a shock is felt, which is repeated as often as the contact is renewed. The principal objections to this construction of the pile, or battery, is the trouble of placing the pieces in the proper order, and also that of cleaning the pieces of zinc, which are rapidly oxydated. The best method of doing this, is by a file, or by putting them into diluted muriatic acid, which dissolves the oxyd.

The battery, Fig. 8, consists of a row of wine glasses, or cups, containing salt and water, or nitrous acid and water. Into each of these is plunged a plate of zinc, and another of silver. These plates are made to communicate with each other by means of a thin wire, fastened so that the silver of the first glass is connected with the zinc of the second, the silver of the second with the zinc of the third, and so on progressively through the whole chain of glasses. When one hand is dipped into the first glass, and another into the last, the shock is perceived.

But though this machine will continue in action a very long time, and when the pieces of zinc are oxydated, they may be easily taken out and cleaned; yet it occupies a great deal of room, when an apparatus of considerable power is wanted.

The battery represented in Fig. 9, is found much more convenient, not being liable to the objections of the two last. It consists of a trough of baked wood, about three inches deep, and about as broad. In the sides of this vessel are grooves opposite to each other, and about a quarter of an inch apart. Into each pair of these opposite grooves is

put a plate of zinc and silver, or zinc and copper soldered together. These plates are well fixed in the grooves, in the proper order of silver and zinc, silver and zinc, as in the pile, by a cement made of five parts of resin, four of bees-wax, and two parts of powdered red ochre. This cement must be run in very carefully, so as absolutely to prevent any communication between the different cells, which would entirely prevent the action of the machine. The cells are then filled with water containing a little acid, common salt, or muriate of ammonia.

When a communication is made between the first and last cell, by means of the hands, a strong shock is felt.

Instead of silver, or copper and zinc, any of the above-mentioned combinations will answer.

The action of all these batteries is greatest, when they are first completed, or filled with the fluid; and it declines in proportion as the metal is oxydated, or the fluid loses its power. Hence, after a certain time, not only the fluid must be changed, but the metallic pieces must be cleaned by removing the oxydated surface, which is done either by filing or by rubbing them with sand-paper, or by weak muriatic acid, which dissolves the oxyd.

When a galvanic battery of the first order (the action of those of the second order being weaker, and much more transient), consists of twenty repetitions of simple combinations, if you touch with one hand one extremity of the battery, and apply your other hand to the other extremity, you will feel a very slight shock, like that which is communicated by a Leyden phial weakly charged, and it will be hardly felt beyond the fingers, or at most the wrists. This shock is felt as often as you renew the contact. If you continue your hands in contact with the extremities, you will perceive a slight but continued irritation; and when the hand, or the other part of the body which touches the other extremity of the battery, is excoriated or wounded, this sensation is disagreeable, and rather painful.

The intensity of the charge is, however, so low, that it cannot make its way through the dry skin of the hand, which is but an imperfect conductor: the fingers should therefore be well moistened with water. It will be better to immerse a wire that proceeds from one extremity of the battery in a bason of water, wherein you may plunge one of your hands; then grasping with your other hand well moistened a large piece of metal, for instance a large silver spoon, touch the other end of the battery with it, and the shock will be felt more distinctly.

Several persons may receive the shock together, by joining hands in the same manner as in receiving the shock from a Leyden phial. For this purpose, the hands must be well moistened with water. But the strength of the shock is much diminished by passing through so long a circuit, the last person feeling it much less violently than the first. In general, its effect is lessened by passing through imperfect conductors.

The galvanic shock is similar to that from a common electrical battery weakly charged, and not like a small Leyden phial fully charged. The difference appears to consist in this, that the latter contains a small quantity of the electric fluid much condensed, so that it can force its way through a certain distance, perhaps an inch of air; but the former contains a vast quantity of the electric fluid, in a very rare, or little condensed state: it cannot, therefore, force a passage through the air,

and the substances that form the communication must come into actual contact, or very nearly so. Thus a discharge of a very powerful battery will not take place, if the wires forming the communication be more than a fortieth of an inch apart.

It appears very probable, that a galvanic battery puts into action a great quantity of the electric fluid, in a state little condensed. From the circumstance of the substances of which the pile is composed being all good conductors of electricity, it would appear, that the electric fluid in a galvanic battery cannot be in a very condensed state, otherwise it would easily pass from one end to the other, and restore the equilibrium. And, indeed, it is not easy to be conceived why this does not always happen.

In this case a small but very vivid spark is seen at the points of the wires, accompanied with a pretty loud snapping noise. There is no perceptible difference of appearance between the spark of the positive, and that of the negative end of the battery.

If a wire proceeding from one extremity of a pretty strong galvanic battery, be made to communicate with the inside coating of a common large jar, or electrical battery, and a wire which proceeds from the other extremity be made to communicate with the outside coating: the latter will become weakly, but almost instantaneously, charged, in the same manner as if it had been charged by a few turns of a common electrical machine; and with that charge you may produce the same effects as by an equal quantity of common electricity.

The shock from a battery consisting of 50 or 60 pairs of zinc and silver, or zinc and copper, may be felt as far as the elbows: and the combined force of five or six such batteries will give a shock that few men would be willing to receive. The prepared limbs of a frog, or other animal, are violently convulsed, but soon exhausted of their irritability by the action of this battery.

The spark from a galvanic battery acts with astonishing activity upon inflammable bodies when sent through them. It fires gunpowder, ether, spirit of wine, cotton, hydrogene gas, phosphorus, &c. it renders red hot, fuses, and consumes very slender metallic wires, and metallic leaves, as tin-foil, gold, silver, and brass-leaf. The method of making these experiments is as follows: having filled the cells of the battery (Fig. 9.) with water containing a little nitrous acid (about one-tenth of acid will form a very active fluid), wipe carefully the edges of the plates with a towel, to prevent any communication between the cells. Having fastened bits of copper to the ends of two pieces of wire, as Fig. 10, of which annealed copper wire is the best, insert them into the fluid in each of the extreme cells, as in Fig. 9. Upon the other ends of the wires, slip on a bit of small glass tube to lay hold of the wires by. After a few minutes the acid will act upon the plates; and if the points of the wires be brought near to each other by moving them by the glass tubes, a spark will be perceived between them. Some of the inflammable substance intended to be acted upon may be laid upon a plate of glass, or put between the points of the wires. In this manner the combustion of gold and silver leaf, &c. may be shewn, forming some of the most beautiful experiments that have ever been exhibited. Copper or brass leaf, commonly called Dutch gold, burns with a beautiful green light, silver with pale blue light, and gold with yellow light, and all

with a crackling something analogous to the noise heard in the burning of paper rubbed over with wet gun-powder.

When very great power is wanted, several of these batteries may be united, by placing them together, as in Fig. 11. Pieces of copper are cut into the form shewn by Fig. 12, and bent as in Fig. 13: the bent ends of these pieces being inserted into the adjoining cells, at the extremities of each battery, a communication is formed from the end A of the first battery, to the end B of the last battery. If wires be now placed in these ends, in the same manner as in the battery Fig. 9, the collected force of the whole will be exhibited at the points of the wires.

It is usual to make these batteries with 50 pairs of metallic plates in each, so that four batteries contain 200 pairs of plates, which are sufficient to produce all the effects above-mentioned in the most satisfactory manner. Two of these batteries will, if properly prepared, exhibit most of the usual experiments.

One of the most extraordinary effects of the galvanic pile or battery, is the apparent decomposition of water. Fill a small glass tube with distilled water, and fitting a cork to each extremity, as in Fig. 14, make a piece of brass or copper wire pass through each of the corks into the water. Connect then the wire A with one of the extremities of the battery, while the wire B communicates with the other extremity. You will then find, that minute bubbles of gas proceed in a constant stream from the end of the wire which passes from the negative end of the battery, and ascending to the upper part of the tube, accumulate by degrees. This gas, if examined, will be found to be hydrogene, and may be inflamed by the approach of an ignited body on pulling out the cork. At the same time the other wire deposits a stream of oxyd in the form of a cloud, which gradually accumulates on the sides and bottom on the tube. If you interrupt the circuit, the streams of gas and oxyd disappear, but are renewed again upon restoring the communication.

In this experiment it would appear, that the hydrogene is separated from the water, and is converted into a gaseous state by the wire connected with the negative extremity of the battery: whilst the oxygene unites with, and oxydates the wire connected with the positive end of the battery. If you connect the positive end of the battery with the lower wire of the tube, and the negative with the upper, then the hydrogene proceeds from the upper wire, and the lower wire is oxydated.

If two wires of gold or platina be used, which are not oxydable, then the streams of gas issue from each, the water is diminished, and the collected gas is found to be a mixture of hydrogene and oxygene, and explodes violently on the approach of an ignited body, or by the electric or the galvanic shock.

To obtain these gases separately, let the two ends of the gold wires be immersed in a vessel of water (Fig. 15), and be about one inch apart. Then hang over them two wine-glasses, inverted, and full of water. The gases will then ascend into the separate vessels.

It is well known that hydrogene gas, in its nascent state, reduces the oxyds of metals. Accordingly, when the tube (Fig. 14) is filled with a solution of acetite of lead in distilled water, and a communication is made with the battery as above described, no gas is perceived to issue from the wire which proceeds from the negative end of the battery; but in a few minutes, beautiful metallic needles are perceived on the

extremity of this wire; these soon increase, and assume the form of fern, or other vegetables. The lead thus separated is in its perfect metallic state, and very brilliant.

The preceding facts can hardly leave any doubt with respect to the identity of the galvanic power, and the electricity which is produced by means of a common electrical machine, or that which is brought down from the clouds; but what is still more remarkable, it reconciles to the same principle the animal electricity, viz. the power of the torpedo, gymnotus electricus, &c. since all the phenomena of the animal electricity agree with those of the galvanic battery. The electric organ of any of the above-mentioned fishes, seems to be constructed exactly like a galvanic battery; for it consists of little laminæ, or pellicles, arranged in columns, and separated by moisture.

The resemblance between the effects of galvanic and common electricity in decomposing water where the latter seemed to fail, has been confirmed by an experiment of Dr. Woolaston, in which, with a very simple apparatus, he decomposed water, by a current of electricity from the prime conductor of an electrical machine.

He likewise remarks another strong point of analogy between the electricity of galvanism and that of the common electrical machine, viz. that they both seem to depend upon oxydation. In fact, a common electrical machine will act more or less powerfully, according as the amalgam which is applied to its rubber consists of metals that are more or less oxydable.

The energy of galvanism as a medical agent, remains yet to be investigated; but when we consider the effects which a very small quantity of this influence produces on the muscles of an animal, even after it is deprived of life, it is not, we think, unreasonable to predict, that a current of galvanic electricity sent for a considerable time through a diseased part, may be productive of the best effects.

The most extraordinary phenomena of a galvanic battery, are the chemical effects and the modifications produced by it on the parts concerned, or on such as are placed in the circuit; and the circumstance has led, in the hands of Sir Humphrey Davy, to the most important discoveries. It would be useless and impossible to describe all the minutiæ, the machinery and experiments, but we shall endeavour to detail in a popular yet distinct form, the nature and extent of Sir Humphrey's surprising discoveries.

By far the most important agency of galvanism, is that by which it gives rise to chemical decomposition. Of all the forces which counteract attraction, and of course subvert combination, it is the most energetic; and as by enlarging the apparatus producing it, it may be accumulated to any degree of intensity, there is apparently no limitation to its power. Chemistry has thus been put in possession of an agent more powerful than any it before possessed, and the most splendid discoveries have been effected by its application. Sir Humphrey Davy, led by the knowledge of the law by which the agency of this power in producing decomposition is regulated, submitted to its action a number of substances, the composition of which was previously to this entirely unknown. The application was successful; the chemical constitution of the alkalies, the earths, and certain acids, has been established, and a series of substances discovered, which were before entirely unknown.

It may be observed, that the decomposition of compounds by the

action of galvanism is obtained by placing them in connection with metallic wires, proceeding from the two extremities of the galvanic battery. The elements of the compound are separated, and may be obtained in their insulated form. If the wires, for instance, are placed in water, the elements of the water are immediately disjoined; and as they are gaseous bodies they assume the elastic form, and are disengaged. Other compound liquids are decomposed with equal facility, as are likewise many solids. These decompositions presented considerable difficulties with regard to their theory, particularly from the singular phenomenon which had been observed, that the elements of the compound, when decomposed, are not evolved together, but that one is given out at the wire connected with one extremity of the galvanic battery, and the other at the wire connected with the opposite side; and this even when the wires are placed in separate portions of the compound, provided these are connected by a conductor of galvanism. To account for this, different hypotheses were framed. At length it was perceived, that when electricity passes through a liquid, the principles or elements of that liquid separate themselves in such a manner, that some unite around the positive pole, and others around the negative; inflammable bodies, alkalies, and earths, passing to the negative; oxygene, acids, and oxydated bodies, passing to the positive. On this same principle, that the one pole of a galvanic series attracts certain elements, while the other pole attracts the others, an explanation was given of the decomposition of water, and of metallic solutions, by galvanism; oxygene being attracted to the positive, hydrogen and metals to the negative side. By the researches of Sir H. Davy, this law has been more clearly developed, more fully established, and its agency better traced.

The law is this: that different chemical agents have such a relation to galvanism, that some are attracted forcibly to the positive, others to the negative side of the galvanic battery: oxygene, and those compounds in which it is most predominant, particularly the acids, being attracted to the former; while inflammable bodies, metals, metallic oxydes, and the earths are attracted to the latter: or, as the law is stated by Sir Humphrey Davy, galvanism and electricity being considered as identical, certain substances, as those above enumerated, are attracted by positively electrified metallic surfaces, and repelled by similar surfaces negatively electrified; while other bodies are attracted by negatively electrified metallic surfaces, and repelled by those which are in a positive state. In consequence of this law, if the compound of oxygene and an inflammable body be subjected to the action of galvanism, the oxygene is attracted by the wire in the positive state, while it is repelled by that which is negative; and, on the other hand, the inflammable ingredient is attracted by the negative wire, and repelled by the other.

The experiments by which these results and the law deduced from them have been established are decisive; but into a description of them we cannot enter. It may, however, be observed, that there has not, in the progress of chemical investigation, been a more brilliant series of discoveries than those effected by Sir Humphrey Davy, by the application of galvanism. They have not only extended the boundaries of chemistry, by the decomposition of a number of substances, the analyses of which had not before been effected, and by the introduction of others before unknown, possessed of very peculiar and active powers, but

they present views extensively connected with the relations of the science, and which will unquestionably influence its future progress.

Among the classes of chemical agents, the alkalies and earths are strictly connected by their general powers, and they possess, in particular, to the same extent, the most important property by which they are characterised. The leading property distinctive of the alkalies is displayed in their relations to the acids: these two classes are in a measure opposed to each other: in entering into combination, the acids always diminish the alkaline properties; the alkalines are equally subversive of the property of acidity; and, when united in a certain proportion, the properties of neither appear in the compound. The same agency is exerted by the earths and the metallic oxydes. Thus, in the most important chemical character of these substances that displayed in their relation to acids, the alkalies, earths, and metallic oxydes, are strictly connected; and the constitution of the last being known, analogy would have led to the conclusion that the others are of a similar nature, or that the earths and alkalies consist of metallic bases combined with oxygen. At length the discoveries of Sir Humphry Davy have fully established the analogy, and have demonstrably proved that they consist of metallic bases combined with oxygen. After these discoveries, ammonia appeared insulated in composition, though in its properties so strictly connected with the alkalies. Sir H. Davy, however, upon submitting it to a new analysis, discovered, what had not before been suspected, viz. that oxygen enters into its composition, and further experiments have shewn that its base is of a metallic nature. Thus, the analogy which connects all the substances, distinguished by the important chemical property of neutralising acids, into one series, is extended to their composition; and all the salifiable bases, as they have been named, comprehending the alkalies, earths, and metallic oxydes, are shewn to be of similar chemical constitution. This must be regarded as a most happy generalization established by the genius and labour of one philosopher.

The experiment which exhibited to this great chemist the decomposition of one of the fixed alkalies is thus described by himself:—" A small piece of pure potass, sufficiently moistened by the atmospheric air to give a conducting power to the surface, was placed upon an insulated disk of platina, connected with the negative side of the battery, in a state of intense activity, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. Under these circumstances, a vivid action was soon observed to take place. The potass began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower, or negative surface, there was no liberation of elastic fluid; but small globules, having a high metallic lustre, and being precisely similar in visible characters to quicksilver, appeared; some of these burnt with an explosion and bright flame as soon as they were formed, and others remained, were tarnished, and finally covered by a white film which formed on their surfaces."

The platina was found to have no share in the production of this new metallic substance, as it was equally produced when other metals, or even charcoal, were employed for completing the electrical circuit. By these analytic experiments, potass is proved to be a compound of a peculiar substance, highly inflammable, and having metallic lustre

and oxygen. This has likewise been confirmed by further experiments It is found that the pure alkaline substance consists of about 86 parts of metallic base, and 14 of oxygen. The metallic base has been named by the discoverer—Potassium: this substance at the temperature of 60° of Fahrenheit appears in small globules, very like the globules of quicksilver; and at this temperature it is imperfectly fluid: but at 70° it is more liquid and mobile; and at 100° it is so completely fluid that the different globules easily run into one. At 50° it becomes solid and malleable, and at 32° it is harder, and even brittle, displaying, when broken, a chrystallized texture. Though so fusible, it is not very volatile, but requires a temperature approaching to a red heat to convert it into vapour. It is a perfect conductor of electricity, and is a good conductor of heat. In regard to its specific gravity, it is lighter than water, or even alcohol, or ether, being in respect to water in the proportion of 6 to 10. In its solid form it is rather heavier.

Potassium, when brought into contact with water, decomposes it with great violence; an explosion is produced with flame, and potass is again formed. Placed on ice, it instantly burns with a bright flame, melting the ice. So strong is the action of this substance on water, that it discovers, by the decomposition which it produces, the smallest quantity of water in other liquids, as in alcohol, or ether.—These are some of the remarkable properties of potassium.

Previously to Sir Humphrey Davy's discoveries, the nature of soda, the other fixed alkali, was as completely unknown as that of potass; but when a small portion of this substance was submitted to the action of the galvanic battery, in the same way as the potass had been operated upon, the result was similar, viz. globules of a metallic appearance were produced at the negative surface, which often burnt at the moment of their formation, and sometimes exploded with violence, separating into smaller globules, which darted through the air in a state of vivid combustion. When they were produced, an aëriform fluid was disengaged at the positive surface, which proved to be pure oxygen. To effect this decomposition, a greater intensity of galvanic action was required than was necessary to decompose potass. The reproduction of soda from this substance was similar to that of the potass from the metallic base of that alkali. When the base of soda was exposed to the air, a crust of alkali formed on its surface, and oxygene was absorbed. When heated in a portion of oxygen gas, a rapid combustion took place, accompanied with a brilliant white flame, and soda was produced in the state of a solid white mass. The philosopher found that 100 parts of soda consist of about 78·5 of base, and 21·5 of oxygen; of course the metallic base of soda combines with a larger proportion of oxygen than the base of potass. This base, from its analogy to metals, was named by the discoverer sodium. It is, in appearance, white and opaque, something like silver. It is exceeding malleable, and much softer than any of the common metallic substances. When pressed upon by a blade of platina with a small force, it spreads into thin leaves, and a globule of the one-tenth or one-twelfth of an inch in diameter is easily spread over a surface of a quarter of an inch. It is a good conductor of heat and electricity. Its specific gravity is less than that of water, or nearly in the proportion of 9 to 10. When sodium is exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white crust, which diliquesces much more

slowly than the substance which forms on the base of potass. This crust is very pure soda. It combines slowly with oxygen, and without any luminous appearance, at common temperatures; and when heated, this combination becomes more rapid; but no light is emitted till it has acquired a temperature nearly that of ignition. The flame that is produced in oxygen-gas is white, and it sends forth bright sparks; in common air, it burns with light of the colour of that produced during the combustion of charcoal, but brighter. When thrown upon water, it produces a violent effervescence, with a loud hissing noise; it combines with the oxygen of the water, and forms soda, which is dissolved, and the hydrogen of the fluid escapes.

Sodium, when thrown upon strong acids, acts upon them with great energy. It combines with metals; and in the quantity of only one-fortieth part, it renders mercury a fixed solid of the colour of silver, and the combination is attended with a considerable degree of heat. It makes an alloy with tin, and it acts upon gold and lead when heated.

Ammonia was regarded as a compound of hydrogen and oxygen; and it has been found by Sir Humphrey Davy to be a compound of oxygen and a metallic base, possessing the most curious properties. Among others it combines with mercury, and renders that fluid metal solid, though only the twelve-thousandth part of the ammonium be used with the mercury; it not only renders the compound solid, but has the effect of reducing the specific gravity from 13, which is that of pure mercury, to 3. In this discovery he was, in some degree, preceded by the Swedish chemists, who from their experiments, to which they had been led by those of Davy, inferred the metallic nature of the base of ammonia, from which they concluded that of the two gases which constitute that alkali.

The discoveries of our English chemist being announced to the public, the experiments which led to them were soon repeated by the philosophers of other countries; and it was unexpectedly found by the chemists of France, that the decomposition of the alkalies was easier than was at first imagined, and might be effected by other ways than electric agency.

The galvanic battery being applied to lime, strontites, and barytes, in the same manner as it had been to the alkalies, a decomposition was observed to take place. Gas was evolved, and metallic globules were produced in contact with the negative wires. But this process could not be completed so as to shew the nature of the products in a satisfactory manner. Potassium, being heated in contact with the alkaline earths, seemed to act upon them, but not to effect their decomposition. Mixtures of potass with the earths, acted upon by the galvanic battery, shewed signs of decomposition. Metallic bodies were produced, less fusible than potassium, burning immediately after their formation, and reproducing the mixture of the alkali and earth employed. While our author was engaged in repeating and varying his attempts to effect the decomposition more readily, he received a letter from Professor Berzelius of Stockholm, stating, that he and Dr. Pontin had completed the process with great ease by other means.

By combining the Swedish method with his own, Sir H. Davy obtained, in considerable quantities, the amalgams of mercury and the bases of the earths. He placed on platina a mixture of the earths, on

which his trials were to be made, and the oxyde of mercury; in this mixture he made a cavity, in which he poured a globule of mercury, and then by the action of the battery it was converted into the amalgam required. The metallic bases thus obtained, in general resemble one another: they are solid, excepting at high temperatures: they are, however, of a greater specific gravity than water; have a light metallic lustre, resembling that of silver, and require a considerable force to flatten them. When exposed to oxygen, they absorb it greedily and return to their native earths.

With silex, argil, zircon, and glucine, the success was much less perfect; but when they were submitted to the action of galvanism, combined with potass and soda in fusion, appearances were obtained which indicated their decomposition, and the production of bases of a metallic nature. Hence it is inferred that all the earths are compounds of bases somewhat analogous to those of the fixed alkalies.

We may give the analysis of the earth barytes as an illustration of the methods adopted in the case of the others. Sir H. Davy, by placing barytes slightly moistened, either alone or mixed with potass, in the galvanic circuit, obtained indistinct appearances of metallization; but the complete reduction was best obtained, as has been remarked, in the mode of experiment performed by Berzelius and Pontin, negatively electrifying the earth in contact with quicksilver. On repeating this experiment with a powerful galvanic battery, it was found that the mercury became less fluid: on exposing this amalgam to the air, it was covered with a film of barytes; and when thrown into water, hydrogen was disengaged, and barytes formed: a similar result was obtained from some of the saline combinations of barytes, as the muriate.

Sir H. Davy, having found that the presence of an oxyde of mercury favoured the decomposition of barytes, combined this method with that of the Swedish chemists. The earth slightly moistened, and mixed with one-third of red oxyde of mercury, was placed on a plate of platina, having a cavity to receive a globule of mercury; the whole was covered by a film of naphtha, and the plate was made positive, the mercury negative, by communication with a very powerful galvanic battery. An amalgam was thus obtained; and to procure from this the base of the barytes it was distilled in a tube of glass, bent in the middle, and enlarged, and rendered globular at each extremity, so as to form a kind of retort and receiver; a little naphtha too having been introduced into the tube, and boiled, so as to exclude the air. The quicksilver rose pure by distillation; but it was very difficult to obtain a complete decomposition, a red heat being required for this, and at this heat the base of the earth acted on the glass. The result, therefore, was less perfect than those with regard to the bases of the alkalies; and there remained the uncertainty but that the metallic base procured might have retained in combination a little quicksilver. To the metallic matter obtained from barytes, Sir H. Davy has given the name of barium.

Barium, as obtained by the experiment above described, appeared as a white metal of the colour of silver. It was fixed at all common temperatures, but became fluid at a heat below redness, and did not rise in vapour when heated to a redness in a tube of glass. It acted, however, violently on the glass, producing a black mass, which seemed to contain barytes and a fixed alkaline base in the first degree of oxygen-

ation. When exposed to air, it rapidly tarnished, and fell into a white powder, which was barytes; and when this process was conducted in a small portion of air, oxygen was absorbed. When the base was dropt in water, it acted on it with great violence, sunk to the bottom, producing barytes, and generating hydrogen gas. It not only sunk in water, but even in sulphuric acid, though surrounded by globules of hydrogen: hence it is concluded that it cannot be less than four or five times heavier than water. Whether it owe this in part to a little mercury combined with it, is uncertain. It flattened by pressure, but required for this purpose a considerable force.

Our chemist endeavoured to ascertain the proportions of base and of oxygen in the composition of barytes, but without success. He ascertained, however, that when burned in a small quantity of air, it absorbed oxygen, gained weight in the process, and the earth produced was in the driest state. The conclusion follows, therefore, that barytes is a compound of this base with oxygen.

The decomposition of strontites was effected by the same modes of galvanic analysis, as those applied to the other earths. By negatively electrifying it in contact with mercury, the phenomena denoting the decomposition of the earth, and the addition of metallic matter to the mercury, rapidly took place; and by employing the process which has just been described with respect to barytes, the metallic base of strontites was obtained. Strontium, for so this base was named, has the general characters of the base resulting from barytes; and by exposure to the air, it absorbs the oxygen from it, gains weight, and is converted to the original earth. It is of a considerable specific gravity. Without pursuing the analysis of the other earths, which would be but a repetition, or at least with very little variation, of what has already been said, we may conclude our account of the brilliant discoveries of Sir Humphery, which do so much honour to the present era, with observing, that one object of research was suggested to our author by a very important experiment of the Swedish chemists, already mentioned:—" These ingenious philosophers found that mercury, placed in contact with a solution of ammonia, and negatively electrified, expands in volume, and becomes a soft solid; that this solid, on exposure to air, absorbs oxygen, and reproduces ammonia and mercury; that water is decompounded by it, giving out hydrogen gas, and leaving a solution of ammonia and mercury. The conclusion naturally drawn from this curious experiment was, that ammonia is, as Sir H. Davy himself had formerly supposed, an oxyde with a double basis, composed of hydrogen and nitrogen; but it seems to shew also, that this double basis possesses metallic properties. So unexpected a light could not fail to attract the quick and discerning eyes of our author; and he lost no time in pursuing the track into which it plainly led him. His first repetition of the Swedish experiment suggested a very material improvement on it—the substitution of neutral salt of ammonia, whereby the deoxygenation and amalgamation are effected in the nascent state of that alkali, and are consequently more easily performed. His process was thus the same with that formerly described for deoxygenating the earths; only, that instead of sulphates or muriates of those earths, he exhibited muriate of ammonia. ' The action,' says he, ' of the quicksilver on the salt was immediate. A strong effervescence, with much heat, took place. The globule in a few minutes had enlarged

to five times its former dimensions, and had the appearance of an amalgam of zinc; and metallic chrystallizations shot from it as a centre, round the body of the salt. They had an arborescent appearance; often became coloured at their points of contact with the muriate; and, when the connection was broken, rapidly disappeared, emitting ammoniacal fumes, and reproducing quicksilver.' Carbonate of ammonia gave the same result; only that a manifest decomposition of the acid, and production of carbonaceous matter, accompanies the other phenomena in this case. The bases of the alkalies and earths, united with mercury, and exhibited in this state to ammonia, supplied the place of electricity, and formed an amalgam of the bases of ammonia and mercury. A little of the bases here used for the purpose of deoxygenating the ammonia, adhered to it in the amalgam; but, independently of this consideration, our author seems to think that the experiment in question unites more of the ammoniacal basis to mercury than the process of deoxygenation by electricity. He does not mention, though we must presume, that, in this ingenious and beautiful experiment, the fixed alkalies or earths are produced.

"The singular amalgam discovered by the Swedish chemists may thus be obtained with great ease either by the agency of electricity, or by double elective affinity. But our author preferred the former method, because it is not attended with the admixture of any third substance, giving the amalgam composed solely of mercury, and the bases of ammonia. Having procured a sufficient quantity of it in this way, he examined it by various simple and satisfactory trials. Its principal properties are the following:—At 70° or 80° this body has the consistence of butter; at the freezing point it hardens and chrystallizes; it is not quite three times heavier than water. In water it absorbs oxygen, causing hydrogen gas to be evolved. In air it likewise absorbs oxygen; and, in both cases, ammonia and quicksilver are reproduced. In sulphuric acid it becomes coated with sulphate of ammonia and sulphur. Sixty grains of mercury are amalgamated by one-two-hundredth part of a grain of the compound basis, or one-twelve-thousandth of the weight of the mercury."—*Phil. Trans.* part ii. 1808.

This valuable paper our author concludes with some general speculations concerning the theory of alkaline and earthy bodies, as elucidated by the discoveries which we have now considered. His observations are always ingenious; and whatever comes from so great a discoverer, one so strict in his experimental investigations, and so successful in generalizing them, ought to be received with singular respect. Nevertheless, we shall not follow him through the whole of his queries and reflections, highly useful as they are likely to prove. We shall only state what we conceive to be the legitimate inferences from his experiments, and then notice a few of his most prominent observations.—It is clearly proved that the fixed alkalies, and the alkaline earths, are metallic oxydes; and the proportion of their bases is nearly as well ascertained as those of several metals known for ages to philosophers, and in common life. That alumina, zircon, glucine, and silex, are also metallic oxydes, seems highly probable; but their decomposition has not yet been so completely effected as to render this point altogether certain; and respecting the metals which seem to constitute their bases, we can scarcely be said to know any thing with precision. It is demonstrated that ammonia is a compound of oxygen, with hydrogen

and nitrogen; and that when the oxygen is removed, the hydrogen and nitrogen are capable of entering into a true chemical union with mercury, forming a substance in all respects similar to the amalgams of that body with other metals. It is highly probable, that the hydrogen and nitrogen are united together as a chemical compound, which thus unites with mercury; and that the same compound unites with oxygen to form ammonia. The appearance of amalgamation, as well as the analogy of the other alkaline bodies, leads us to suspect that this compound basis is truly of a metallic nature, and that the volatile, like the fixed alkalies and the alkaline earths, is a metallic oxyde; but this basis has not yet been separately exhibited. Such, in general, is the state of our knowledge upon the constitution of the alkalies and earths, as extended by the late wonderful discoveries; and such is the line to be drawn between what we have strictly learned as physical truths, and what we have been taught to conjecture upon evidence of a lower nature than that of legitimate induction.

The last of these wonders, the constitution of ammonia, gives rise to various hypotheses. To account for the phenomena of amalgamation with mercury and the reproduction of the alkali, three different theories have been stated. Mr. Davy himself seems to think it possible, that hydrogen and nitrogen are both metals, aëriform at common temperatures, as zinc and mercury are when ignited. Mr. Berzelius suggests, that they may be simple bodies, not metallic, but forming a metal when united, without oxygen; and an alkali, when united and oxygenated. Mr. Cavendish has submitted a third conjecture, that these gases, in their common form, may be oxydes, which, when further oxygenated, become metallic.

The labours of Sir Humphrey Davy in this department of science have been unwearied, but they have been crowned with a degree of success, and with discoveries of such importance as no one could have anticipated. Let us consider what we should have said, had such a contribution to chemical knowledge (as that in the Phil. Trans. 1809) fallen in our way ten years ago—had we for instance heard that the basis of the boracic acid had been discovered, that hydrogen had been detected in sulphur and phosphorus, and oxygen in azote? The whole world of letters would have been in commotion, and it would have been universally allowed, that, since the establishment of modern chemistry, no such steps had been made towards its perfection. If we now think less of these improvements, or even receive them with coldness, it is because we have been spoiled with the abundance of capital discoveries in which we have been revelling—and it is Davy himself who has spoiled us. His grand and numerous inventions, together with the two unexpected and important steps made by the French and Swedish chemists, have, for a while, so completely satiated the curiosity of the scientific world, that scarcely any new fact would now excite astonishment.

CHAP. IX.

DYEING.

The substances commonly employed for clothing may be reduced to four: wool, silk, cotton, and linen.

Permanent alterations in the colour of cloth can only be produced two ways; either by producing a chemical change in the cloth, or by covering its fibres with some substance which possesses the wished-for colour. Recourse can seldom or never be had to the first of these methods, because it is hardly possible to produce a chemical change in the fibres of cloth without spoiling its texture, and rendering it useless. The dyer, therefore, when he wishes to give a new colour to cloth, has always recourse to the second method.

The substances employed for this purpose are called *colouring matters*, or *dye stuffs*: they are for the most part extracted from animal and vegetable substances, and have usually the colour they give to the cloth. Hence as the particles of colouring matter, with which cloth when dyed is covered, are transparent, it follows, that all the light reflected from dyed cloth must be reflected, not by the *dye stuff* itself, but by the fibres of the cloth below the *dye stuff*. The colour, therefore, does not depend upon the dye alone, but also on the previous colour of the cloth. If the cloth be black, it is clear that we cannot dye it any other colour whatever: because as no light in that case is reflected, none can be transmitted, whatever dye stuff we employ. If the cloth were red, or blue, or yellow, we could not dye it any colour except black, because as only blue or red or yellow rays were reflected, no other could be transmitted. Hence the importance of a fine white colour when cloth is to receive bright dyes. It then reflects all the rays in abundance, and therefore any colour may be given, by covering it with a dye stuff which transmits only some particular rays.

If the colouring matters were merely spread over the surface of the fibres of cloth by the dyer, the colours produced might be very bright, but they could not be permanent; because the colouring matter would be very soon rubbed off; and would totally disappear whenever the cloth was washed, or even barely exposed to the weather. The colouring matter then, however perfect a colour it possesses, is of no value, unless it also adheres so firmly to the cloth that none of the substances usually applied to cloth, in order to clean it, &c. can displace it. Now this can only happen, when there is a strong affinity between the colouring matter and the cloth, and when they are actually combined together in consequence of that affinity.

Dyeing then is merely a chemical process, and consists in combining a certain colouring matter with fibres of cloth. This process can in no instance be performed, unless the dye stuff be first reduced to its integrant particles; for the attraction of aggregation between the particles of dye stuffs is too great to be overcome by the affinity between them and the cloth, unless they could be brought within much smaller distances than is possible while they both remain in a solid form. It is necessary, therefore, previously to dissolve the colouring matter in some liquid or other, which has a weaker affinity for it than the cloth has.

When the cloth is dipped into this solution, the colouring matter, reduced by this contrivance to a liquid state, is brought within the attracting distance; the cloth therefore acts upon it, and from its stronger affinity, takes it from the solvent, and fixes it upon itself. By this contrivance too, the equality of the colour is in some measure secured, as every part of the cloth has an opportunity of attracting to itself the proper proportion of colouring particles.

The facility with which cloth imbibes a dye depends upon two things; namely, the affinity between the cloth and the dye stuff, and the affinity between the dye stuff and its solvent. It is directly as the former, and inversely as the latter. It is of importance to preserve a due proportion between these two affinities, as upon that proportion much of the accuracy of dyeing depends. If the affinity between the colouring matter and the cloth be too great, compared with the affinity between the colouring matter and the solvent, the cloth will take the dye too rapidly, and it will be scarcely possible to prevent its colour from being unequal. On the other hand, if the affinity between the colouring matter and the solvent be too great, compared with that between the colouring matter and the cloth, the cloth will either not take the colour at all, or it will take it very slowly and very faintly.

Wool has the strongest affinity for almost all colouring matters, silk the next strongest, cotton a considerably weaker affinity, and linen the weakest affinity of all. Therefore in order to dye cotton or linen, the dye stuff should in many cases be dissolved in a substance for which it has a weaker affinity than for the solvent employed in the dyeing of wool or silk. Thus we may use oxyde of iron dissolved in sulphuric acid, in order to dye wool; but for cotton and linen, it is better to dissolve it in acetous acid.

Were it possible to procure a sufficient number of colouring matters, having a strong affinity for cloth, to answer all the purposes of dyeing, that art would be exceedingly simple and easy. But this is by no means the case; if we except indigo, the dyer is scarcely possessed of a dye stuff which yields of itself a good colour, sufficiently permanent to deserve the name of a dye.

This difficulty, which at first sight appears insurmountable, has been obviated by a very ingenious contrivance. Some substance is pitched upon, which has a strong affinity, both for the cloth and the colouring matter. This substance is previously combined with cloth, which is then dipped into the solution containing the dye stuff. The dye stuff combines with the intermediate substance, which being firmly combined with the cloth, secures the permanence of the dye. Substances employed for this purpose are denominated mordants.

The most important part of dyeing is undoubtedly the proper choice, and the proper application of mordants, as upon them the permanency of almost every dye depends. Every thing which has been said respecting the application of colouring matters, applies equally to the application of mordants. They must be previously dissolved in some liquid, which has a weaker affinity to them than the cloth has, to which they are to be applied; and the cloth must be dipped, or even steeped in this solution, in order to saturate itself with the mordant.

Almost the only substances used as mordants, are earths, metallic oxydes, tan, and oil.

Of earthy mordants the most important, and most generally used, is

alumine. It is used either in the state of common alum, in which it is combined with sulphuric acid, or in that of acetite of alumine.

Alum, when used as a mordant, is dissolved in water, and very frequently a quantity of tartar is dissolved along with it. Into this solution the cloth is put, and kept in it till it has absorbed as much alumine as is necessary. It is then taken out, and for the most part washed and dried. It is now a good deal heavier than it was before, owing to the alumine which has combined with it. The tartar serves two purposes; the potass which it contains combines with the sulphuric acid of the alum, and thus prevents that very corrosive substance from injuring the texture of the cloth, which otherwise might happen: the tartareous acid, on the other hand, combines with part of the alumine, and forms a tartrite of alumine, which is more easily decomposed by the cloth than alum.

Acetite of alumine has been but lately introduced into dyeing. This mordant is now prepared by pouring acetite of lead into a solution of alum; a double decomposition takes place, the sulphureous acid combines with the lead, and the compound precipitates, in the form of an insoluble powder, while the alumine combines with the acetous acid, and remains dissolved in the liquid. This mordant is employed for cotton and linen, which have a weaker affinity than wool for alumine. It answers much better than alum; the cloth is more easily saturated with alumine, and takes, in consequence, both a richer and a more permanent colour.

Besides alumine, *lime* is sometimes used as a mordant. Cloth has a strong enough affinity for it; but, in general, it does not answer so well, as it does not give so good a colour. When used, it is either in the state of lime-water, or of sulphate of lime dissolved in water.

Almost all the metallic oxydes have an affinity for cloth, but only two of them are extensively used as mordants, namely, the oxydes of tin, and of iron.

The oxyde of tin was first introduced into dyeing by Kuster, a German chemist, who brought the secret to London in 1543. This period forms an era in the history of dyeing. The oxyde of tin has enabled the moderns greatly to surpass the ancients in the fineness of their colours; by means of it alone, scarlet, the brightest of all colours, is produced.

Tin, as Proust has proved, is capable of two degrees of oxydation. The first oxyde is composed of 0.70 parts of tin, and 0.30 of oxygen; the second, or white oxyde, of 0.60 parts of tin, and 0.40 of oxygen. The first oxyde absorbs oxygen with very great facility, even from the air, and is rapidly converted into white oxyde. This fact makes it certain, that it is the white oxyde of tin alone which is the real mordant; even if the other oxyde were applied to cloth, as it probably often is, it must soon be converted into white oxyde, by absorbing oxygen from the atmosphere.

Tin is used as a mordant in three states: dissolved in nitro-muriatic acid, in acetous acid, and in a mixture of sulphuric and muriatic acids. Nitro muriate of tin is the common mordant employed by dyers. They prepare it by dissolving tin in diluted nitric acid, to which a certain proportion of muriate of soda, or of ammonia, is added. Part of the nitric acid decomposes these salts, combines with their base, and sets the muriatic acid at liberty. They prepared it at first with nitric acid

alone, but that mode was very defective, because the nitric acid very readily converts tin to white oxyde, and then is capable of dissolving it. The consequence of which was, the precipitation of the whole of the tin. To remedy this defect, common salt, or sal ammoniac, was very soon added; muriatic acid having the property of dissolving white oxyde of tin very readily. A considerable saving of nitric acid might be obtained, by employing as much sulphuric acid as is just sufficient to saturate the base of the common salt or sal ammoniac employed.

When the nitro muriate of tin is to be used as a mordant, it is dissolved in a large quantity of water, and the cloth is dipped in the solution, and allowed to remain till sufficiently saturated. It is then taken out, washed, and dried. Tartar is usually dissolved in the water along with the nitro-muriate. The consequence of this is a double decomposition; the nitro-muriatic acid combines with the potass of the tartar, while the tartareous acid dissolves the oxyde of tin. When tartar is used, therefore, in any considerable quantity, the mordant is not a nitro-muriate, but a tartrite of tin.

Iron, like tin, is capable of two degrees of oxydation; but the green oxyde absorbs oxygen so readily from the atmosphere, that it is very soon converted into the red oxyde. It is only this last oxyde which is really used as a mordant in dyeing. The green oxyde is, indeed, sometimes applied to cloth; but it very soon absorbs oxygen, and is converted into the red oxyde. This oxyde has a very strong affinity for all kinds of cloth. The permanency of the iron spots on linen and cotton is a sufficient proof of this. As a mordant, it is used in two states; in that of sulphate of iron, and acetite of iron. The first is commonly used for wool. The salt is dissolved in water, and the cloth dipped in it. It may be used also for cotton, but in most cases acetite of iron is preferred. It is prepared by dissolving iron, or its oxyde, in vinegar, sour beer, &c. and the longer it is kept, the more it is preferred. The reason is, that the mordant succeeds best when the iron is in the state of red oxyde. It would be better then to oxydate the iron, or convert it into rust, before using it; which might easily be done, by keeping it for some time in a moist place, and sprinkling it occasionally with water.

Tan has a very strong affinity for cloth, and for several colouring matters; it is therefore very frequently employed as a mordant. An infusion of *nut-galls* or of *shumack*, or any other substance containing tan, is made in water, and the cloth is dipped in this infusion, and allowed to remain till it has absorbed a sufficient quantity of tan. Silk is capable of absorbing a very great proportion of tan, and by that means acquires a great increase of weight. Manufacturers sometimes employ this method of increasing the weight of silk.

Tan is often employed also, along with other mordants, in order to produce a compound mordant. Oil is also used for the same purpose, in the dyeing of cotton and linen. The mordants with which tan most frequently is combined, are alumine, and oxyde of iron.

Besides these mordants, there are several other substances frequently used as auxiliaries, either to facilitate the combination of the mordant with the cloth, or to alter the shade of colour; the chief of these are, *tartar, acetite of lead, common salt, sal ammoniac, sulphate or acetite of copper*, &c.

Mordants not only render the dye permanent, but have also consi-

derable influence on the colour produced. The same colouring matter produces very different dyes, according as the mordant is changed. Suppose, for instance, that the colouring matter be cochineal; if we use the aluminous mordant, the cloth will acquire a crimson colour; but the oxyde of iron produces with it a black.

In dyeing, then, it is not only necessary to procure a mordant which has a sufficiently strong affinity for the colouring matter and the cloth, and a colouring matter which possesses the wished-for colour in perfection, but we must procure a mordant and a colouring matter of such a nature, that when combined together, they shall possess the wished-for colour in perfection. It is evident too, that a great variety of colours may be produced with a single dye stuff, provided we can change the mordant sufficiently.

The colouring matter with which the cloth is dyed, does not cover every portion of its surface; its particles attach themselves to the cloth at certain distances from each other; for cloth may be dyed different shades of the same colour, lighter or darker, merely by varying the quantity of colouring matter. With a small quantity, the shade is light; and it becomes deeper as the quantity increases: now this would be impossible, if the dye stuff covered the whole of the cloth.

That the particles of colouring matter, even when the shade is deep, are at some distance, is evident from this well known fact, that cloth may be dyed two colours at the same time. All those colours to which the dyers give the name of compound, are in fact two different colours applied to the cloth at once. Thus cloth gets a green colour, by being first dyed blue, and then yellow.

The colours denominated by dyers simple, because they are the foundation of all their other processes, are four; namely, first, blue; second yellow; third, red; fourth, black. To these they usually add a fifth, under the name of root, or brown colour.

Of Dyeing Blue.

The only colouring matters employed in dyeing blue are woad and indigo.

Woad is a plant cultivated in this kingdom, and even growing wild in some parts of England.

Indigo is a blue powder, extracted from a species of plants which is cultivated for that purpose in the East and West Indies. These plants contain a peculiar green pollen, which in that state is soluble in water. This pollen has a strong affinity for oxygen, which it attracts greedily from the atmosphere; in consequence of which it assumes a blue colour, and becomes insoluble in water.

Indigo has a very strong affinity for wool, silk, cotton, and linen. Every kind of cloth, therefore, may be dyed with it, without the assistance of any mordant whatever. The colour thus induced is very permanent; because the indigo is already saturated with oxygen, and because it is not liable to be decomposed by those substances, to the action of which the cloth is exposed. But it can only be applied to cloth in a state of solution; and the only solvent known being sulphuric acid, it would seem at first sight, that the sulphuric acid solution is the only state in which indigo can be employed as a dye.

Wool and silk are often dyed blue by the sulphate of indigo; but it can scarcely be applied to cotton and linen, because the affinity of these substances for indigo is not great enough to enable them readily to decompose the sulphate. The colour given by sulphate of indigo is exceedingly beautiful: it is known by the name of Saxon blue.

One part of indigo is to be dissolved in four parts of concentrated sulphuric acid; to the solution one part of dry carbonate of potass is to be added, and then it is to be diluted with eight times its weight of water. The cloth must be boiled for an hour in a solution, containing five parts of alum and three of tartar for every 32 parts of cloth. It is then to be thrown into a water bath, containing a greater or smaller proportion of the diluted sulphate of indigo, according to the shade which the cloth is intended to receive. In this bath it must be boiled till it has acquired the wished-for colour.

The alum and tartar are not intended to act as mordants, but to facilitate the decomposition of the sulphate of indigo. The alkali, added to the sulphate, answers the same purpose. These substances also, by saturating part of the sulphuric acid, serve in some measure to prevent the texture of the cloth from being injured by the action of the acid, which is very apt to happen in this process.

But sulphate of indigo is by no means the only solution of that pigment employed in dyeing. By far the most common method is, to deprive indigo of the oxygen, to which it owes its blue colour, and thus to reduce it to the state of green pollen: and then to dissolve it in water by means of alkalies, or alkaline earths, which in that state act upon it very readily.

Two different methods are employed for this purpose. The first of these methods is, to mix with indigo a solution of some substance which has a stronger affinity for oxygen than the green bases of indigo; green oxyde of iron, for instance, and different metallic sulphurets. If, therefore, indigo, lime, and green sulphate of iron, be mixed together in water, the indigo gradually loses its blue colour, becomes green, and is dissolved; while the green oxyde of iron is converted into the red oxyde. The manner in which these changes take place is obvious; part of the lime decomposes the sulphate of iron; the green oxyde, the instant that it is set at liberty, attracts oxygen from the indigo, decomposes it, and reduces it to the state of green pollen. This green pollen is immediately dissolved by the action of the rest of the lime.

The second method is, to mix the indigo in water with certain vegetable substances, which readily undergo fermentation. During this fermentation, the indigo is deprived of its oxygen, and dissolved by means of quick-lime or alkali, which is added to the solution. The first of these methods is usually followed in dyeing cotton and linen; the second in dyeing wool and silk.

In the dyeing of wool, woad and bran are commonly employed as vegetable ferments, and lime as the solvent of the green base of the indigo. Woad contains itself a colouring matter precisely similar to indigo; by following the common process, indigo may be extracted from it. In the usual state of woad, when purchased by the dyer, the indigo which it contains is probably not far from the state of the green pollen. Its quantity in woad is but small, and it is mixed with a great proportion of other vegetable matter.

When the cloth is first taken out of the vat, it is of a green colour; but it soon becomes blue by attracting oxygen from the air. It ought to be carefully washed to carry off the uncombined particles. This solution of indigo is liable to two inconveniences: first, it is apt sometimes to run too fast into the putrid fermentation; this may be known by the putrid vapours which it exhales, and by the disappearing of the green colour. In this state it would soon destroy the indigo altogether. The inconvenience is remedied by adding more lime, which has the property of moderating the putrescent tendency. Secondly, sometimes the fermentation goes on too languidly. This defect is remedied by adding more bran or woad in order to diminish the proportion of quick-lime.

Silk is died light blue by a ferment of six parts of bran, six of indigo, six of potass, and one of madder. To dye it of a dark blue, it must previously receive what is called a ground colour; archil is used for this purpose.

Cotton and linen are dyed blue by a solution of one part of indigo, one part of green sulphate of iron, and two parts of quick-lime.

Of Dyeing Yellow.

The principal colouring matters for dyeing yellow are weld, fustic, and quercitron bark.

Weld is a plant which grows commonly in this country.

Fustic is the wood of a large tree which grows in the West Indies.

Quercitron is a tree growing naturally in North America, the bark of which contains colouring matter.

Yellow colouring matters have too weak an affinity for cloth to produce permanent colours without the use of mordants. Cloth, therefore, before it be dyed yellow, is always prepared by combining some mordant or other with it. The mordant most commonly employed for this purpose is alumine. Oxyde of tin is sometimes used when very fine yellows are wanting. Tan is often employed as a subsidiary to alumine, and in order to fix it more copiously on cotton and linen. Tartar is also used as an auxiliary to brighten the colour; and muriate of soda, sulphate of lime, and even sulphate of iron, in order to render the shade deeper.

The yellow dyed by means of fustic is more permanent, but not so beautiful as that given by weld or quercitron. As it is permanent, and not much injured by acids, it is often used in dyeing compound colours where a yellow is required. The mordant is alumine. When the mordant is oxyde of iron, fustic dyes a good permanent drab colour.

Weld and quercitron bark yield nearly the same kind of colour; but as the bark yields colouring matter in much greater abundance, it is much more convenient, and, upon the whole, cheaper than weld. It is probable, therefore, that it will gradually supersede the use of that plant. The method of using each of the dye stuffs is nearly the same.

Wool may be dyed yellow by the following process: let it be boiled for an hour or more with about one-sixth of its weight of alum, dissolved in a sufficient quantity of water. It is then to be plunged, without being rinsed, into a bath of warm water, containing in it as

much quercitron bark as equals the weight of the alum employed as a mordant. The cloth is to be turned through the boiling liquid till it has acquired the intended colour. Then a quantity of clean powdered chalk, equal to the hundredth part of the weight of the cloth, is to be stirred in, and the operation of dyeing continued for eight or ten minutes longer. By this method a pretty deep and lively yellow may be given, fully as permanent as weld yellow.

For very bright orange or golden yellow, it is necessary to have recourse to the oxyde of tin as a mordant.

For producing bright golden yellows, some alum must be added along with the tin.

In order to give the yellow that delicate green shade so much admired for certain purposes, tartar must be added in different proportions according to the shade.

By adding a small proportion of cochineal, the colour may be raised to a fine orange, or even an aurora.

Silk may be dyed different shades of yellow, either by weld or quercitron bark, but the last is the cheapest of the two. The proportion should be from one or two parts of bark to twelve parts of silk, according to the shade. The bark, tied up in a bag, should be put into the dyeing vessel, while the water which it contains is cold; and when it has acquired the heat of about 100°, the silk having been previously alumed, should be dipped in, and continued till it assumes the wished-for colour. When the shade is required to be deep, a little chalk or pearl-ash should be added towards the end of the operation.

Cotton and linen are dyed yellow as follows:

The mordant should be acetite of alumine, prepared by dissolving one part of acetite of lead, and three parts of alum, in a sufficient quantity of water. This solution should be heated to the temperature of 100°, the cloth should be soaked in it for two hours, then wrung out and dried. The soaking may be repeated, and the cloth again dried as before. It is then to be barely wetted with lime water, and afterwards dried. The soaking in the acetite of alumine may be again repeated, and if the shade of yellow is required to be very bright and durable, the alternate wetting with lime water and soaking in the mordant may be repeated three or four times.

By this contrivance, a sufficient quantity of alumine is combined with the cloth, and the combination is rendered more permanent by the addition of some lime. The dyeing bath is prepared by putting twelve or eighteen parts of quercitron bark (according to the depth of the shade required), tied up in a bag, into a sufficient quantity of cold water. Into this bath the cloth is to be put, and turned round in it for an hour, while its temperature is gradually raised to about 120°; it is then to be brought to a boiling heat, and the cloth allowed to remain in it after that only a few minutes. If it be kept long at a boiling heat, the yellow acquires a shade of brown.

Nankeen yellow is obtained by a solution of the red sulphate of iron, which is combined with the cloth by carbonate of potass.

Of Dyeing Red.

The colouring matters employed for dyeing red are kermes, cochineal, archil, madder, carthamus, Brazil-wood, lac, and logwood.

Kermes is a species of insect, affording a red colour by solution in water; but it is not so beautiful as cochineal, which is likewise an insect brought from America. The decoction of cochineal is a very beautiful crimson colour. Alum brightens the colour of the decoction, and occasions a crimson precipitate. Muriate of tin gives a copious fine red precipitate.

Archil is a paste formed of a species of lichen pounded, and kept moist for some time with stale urine.

Madder is the root of a well known plant *(rubia tinctorium)*.

Carthamus is the flower of a plant cultivated in Spain and the Levant. It contains two colouring matters: a yellow, which is soluble in water; and a red, insoluble in water, but soluble in alkaline carbonates. The red colouring matter of carthamus, extracted by carbonate of soda, and precipitated by lemon juice, constitutes the rouge employed by ladies as a paint. It is afterwards ground with a certain quantity of talc. The fineness of the talc, and the proportion of it mixed with the carthamus, occasion the difference between the cheaper and dearer kinds of rouge.

Brazil-wood is the wood of a tree growing in America and the West Indies. Its decoction is a fine red colour.

None of the red colouring matters has so strong an affinity for cloth as to produce a permanent red, without the assistance of mordants. The mordants employed are alumine, and oxyde of tin; oil, and tan, in certain processes, are also used, and tartar, and muriate of soda, are frequently called in as auxiliaries.

Lac is the production of an insect brought from india. The decoction of it in water gives a deep crimson colour.

Logwood, called also Campeachy-wood, is the wood that grows in Jamaica and the bay of Campeachy. It gives out its colouring matter, which is of a fine red, copiously to alkohol, and more sparingly to water.

Wool may be died red with madder or archil, but these are used only for coarse woollen stuffs. The stuffs are first boiled for some hours in alum and tartar, and then wrung out. After remaining some days, they are boiled in a decoction of madder.

Scarlet is the most splendid of all reds, but is of different shades, like other colours. Alumine was formerly used as a mordant for fixing the cochineal which is used for dyeing red, but nitro-muriat of tin is now employed for this purpose, as it gives a brighter colour to the cochineal. To dye woollen cloth scarlet, it is first boiled in a bath of pure tartar, to which a little cochineal has been added, and also nitro-muriat of tin. After this it is well washed, and then subjected to a second bath of cochineal, which is called the reddening. Sometimes they do not change the bath, but add the reddening to the first bath.

As the red produced by cochineal alone is rather a crimson than a bright scarlet, to produce the latter it is necessary first to dye the cloth yellow, and after crimson, as bright scarlet is a compound

of crimson and yellow. This is done by the use of fustic, turmeric, or quercitron bark, in the first bath, to produce the yellow; the second bath is cochineal alone, which naturally gives a crimson tinge.

When crimson is the colour required to be dyed, the tin mordant is the best, but sometimes dyers use alum baths for this purpose, and then a decoction of cochineal. The addition of archil and potass to the cochineal renders the crimson darker, and gives it more bloom, but this is very fugacious. For paler crimsons, a portion of madder is substituted for part of the cochineal.

Silk is usually dyed red with cochineal or carthamus, and sometimes with Brazil-wood. Kermes does not answer for silk; madder is scarcely ever used for that purpose, because it does not yield a colour bright enough. Archil is employed to give silk a bloom; but it is scarcely used by itself, unless when the colour wanted is lilac.

Silk may be dyed crimson by steeping it in a solution of alum, and then dyeing it in the usual way in the cochineal bath.

The colours known by the names of poppy, cherry, rose, and flesh-colour, are given to silk by means of carthamus. The process consists merely in keeping the silk, as long as it extracts any colour, in an alkaline solution of carthamus, into which as much lemon juice as gives it a fine cherry colour, has been poured.

Silk cannot be dyed a full scarlet; but a colour approaching to scarlet may be given it, by first impregnating the stuff with murio-sulphate of tin, and afterwards dyeing it in a bath composed of four parts of cochineal, and four parts of quercitron bark. To give the colour more body, both the mordant and the dye may be repeated. A colour approaching scarlet may be also given to silk by first dyeing it crimson, then dyeing it with carthamus, and lastly yellow without heat.

Cotton and linen are dyed red with madder. The process was borrowed from the east. Hence the colour is often called Adrianople, or Turkey-red. The cloth is first impregnated with oil, then with galls, and lastly with alum. It is then boiled for an hour in a decoction of madder, which is commonly mixed with a quantity of blood. After the cloth is dyed, it is plunged into a soda lye, in order to brighten the colour. The red given by this process is very permanent, and when properly conducted, it is exceedingly beautiful. The whole difficulty consists in the application of the mordant, which is by far the most complicated employed in the whole art of dyeing.

Cotton may be dyed scarlet by means of murio-sulphate of tin, cochineal, and quercitron bark, used as for silk, but the colour is too fading to be of any value.

Of Dyeing Black.

The substances employed to give a black colour to cloth are, red oxyde of iron and tan. These two substances have a strong affinity for each other; and when combined, assume a deep black colour, not liable to be destroyed by the action of air or light.

Logwood is usually employed as an auxiliary, because it communicates lustre, and adds considerably to the fullness of the black. Logwood yields its colouring matter to water. The decoction is at first a fine red, bordering on violet; but, if left to itself, it gradually assumes a

black colour. Acids give it a deep red colour; alkalies a deep violet inclining to brown; sulphate of iron renders it as black as ink, and occasions a precipitate of the same colour.

Cloth, before it receives a black colour, is usually dyed blue: this renders the colour much fully and finer than it would otherwise be. If the cloth be coarse, the blue dye may be too expensive; in that case a brown colour is given by means of walnut-peels.

Wool is dyed black by the following process: it is boiled for two hours in a decoction of nut-galls, and afterwards kept for two hours more in a bath composed of logwood and sulphate of iron, at a scalding heat, but not boiled. During the operation, it must be frequently exposed to the air; because the green oxyde of iron, of which the sulphate is composed, must be converted into red oxyde by absorbing oxygen, before the cloth can acquire a proper colour. The common proportions are, five parts of gall, five of sulphate of iron, and thirty of logwood, for every hundred of cloth. A little acetite of copper is commonly added to the sulphate of iron, because it is thought to improve the colour.

Silk is dyed nearly in the same manner. It is capable of combining with a great deal of tan: the quantity given is varied at the pleasure of the artist, by allowing the silk to remain a longer or shorter time in the decoction.

Linen and cotton are not easy to dye of a full black. The cloth, previously dyed blue, is steeped for twenty-four hours in a decoction of nut-galls. A bath is prepared, containing acetite of iron, formed by saturating acetous acid with brown oxyde of iron: into this bath the cloth is put in small quantities at a time, wrought with the hand for a quarter of an hour, then wrung out, and aired again; next wrought in a fresh quantity of the bath, and afterwards aired. These alternate processes are repeated till the colour wanted is given. A decoction of alder-bark is usually mixed with the liquor containing the nut-galls.

Of Dyeing Brown.

Brown, or fawn-colour, though in fact a compound, is usually ranked among the simple colours, because it is applied to cloth by a single process. Various substances are used for brown dyes.

Walnut-peels, or the green covering of the walnut: when first separated, they are white internally, but soon assume a brown, or even a black colour, on exposure to the air. They readily yield their colouring matter to water. They are usually kept in large casks, covered with water, for above a year before they are used. To dye wool brown with them, nothing more is necessary than to steep the cloth in a decoction of them till it has acquired the wished-for colour. The depth of the shade is proportional to the strength of the decoction. The root of the walnut-tree contains the same colouring matter, but in smaller quantity. The bark of the birch also, and many other trees, may be used for the same purpose. It is very probable that the brown colouring matter is in these vegetable substances combined with tan. This is certainly the case in shumac, which is often employed to produce a brown. This combination explains the reason why no mordant is necessary; the tan has a strong affinity for cloth, and the colouring

matter for the tan. The dye stuff and the mordant are already, in fact, combined together.

Of Dyeing Compound Colours.

Compound colours are produced by mixing together two simple ones, or, which is the same thing, by dyeing cloth first one simple colour, and then another. These colours vary to infinity, according to the proportions of the ingredients employed. They may be arranged under the following classes:

Mixtures of, 1st, Blue and yellow; 2d, Blue and red; 3d, Yellow and red; 4th, Black and other colours.

Mixtures of blue and yellow.—This forms green, which is distinguished by dyers into a variety of shades, according to the depth of the shade, or the prevalence of either of the component parts. Thus we have sea-green, grass-green, pea-green, &c.

Wool, silk, and linen, are usually dyed green, by giving them first a blue colour, and afterwards dyeing them yellow; because, when the yellow is first given, several inconveniences follow: the yellow partly separates again in the blue vat, and communicates a green colour to it, and thus renders it useless for every other purpose except dyeing green. Any of the usual processes for dyeing blue and yellow may be followed, taking care to proportion the depth of the shades to that of the green required. When sulphate of indigo is employed, it is usual to mix all the ingredients together, and to die the cloth at once; this produces what is known by the name of Saxon, or English-green.

Mixtures of blue and red.—These form different shades of violet, purple, and lilac. Wool is generally first died blue, and afterwards scarlet, in the usual manner. By means of cochineal mixed with sulphate of indigo, the process may be performed at once. Silk is first dyed crimson by means of cochineal, and then dipped into the indigo vat. Cotton and linen are first dyed blue, then galled, and soaked in a decoction of logwood; but a more permanent colour is given by means of oxyde of iron.

Mixtures of yellow and red.—This produces orange. When blue is combined with red and yellow on cloth, the resulting colour is olive. Wool may be dyed orange by first dyeing it scarlet, and then yellow. When it is dyed first with madder, the result is cinnamon colour.

Silk is dyed orange by means of carthamus; a cinnamon colour by logwood, Brazil-wood, and fustic mixed togather.

Cotton and linen receive a cinnamon colour by means of weld and madder; and an olive colour by being passed through a blue, yellow, and then a madder bath.

Mixtures of black with other colours.—These constitute greys, drabs, and browns. If cloth be previously combined with brown oxyde of iron, and afterwards dyed yellow with quercitron bark, the result will be a drab of different shades, according to the proportion of mordant employed. When the proportion is small, the colour inclines to olive or yellow; on the contrary, the drab may be deepened or saddened, as the dyers term it, by mixing a little shumac with the bark.

VARNISHES.

The liquids in which the substances proper for making varnishes are generally dissolved, are linseed, nut-oil, sunflower-oil, oil of turpentine, spirit of wine. Hence the substances themselves are all of the class of rosins. Nut-oil is not often used, though being of a clearer colour than linseed-oil, it might sometimes deserve the preference. The other essential oils, as rosemary, bergamotte, &c. are too dear, and do not dry.

The substances commonly employed are such as form a transparent solution with the solvents above mentioned, and are not liable to be affected by moisture of any kind: since none of the gums, or gum-resins, are fit for the purpose.

The resins usually employed are, copal, amber, mastic, sandaric, lac (both stick lac and seed lac), pine turpentine from Chios or Venice, common white rosin, dragon's-blood, gum-elemi, asphaltum or Jew's pitch, and common pitch. To which may be added, elastic-gum, or ca-out-chouc, though this is only used at present for balloons.

Oil of turpentine deadens the colour of paints: the varnishes of amber and copal brighten them.

Linseed-oil is procured by grinding linseed in mills for that purpose. It is of a brownish colour. Before it can be used it must be made drying. The reason that oil will not dry without preparation is, either that it contains a quantity of uncombined mucilaginous substance, or a quantity of uncombined acid, or both.

The common method of making drying oil, is to put about half an ounce of litharge to each quart of the oil. Boil it, not hastily or violently, but with a moderate and equal fire, for about two hours, scumming it. If it be boiled too hard, it will be burnt, and become brown. Let this rest till all sediment has perfectly subsided; then separate the clean oil, which will grow the clearer and the better for keeping. When it is made perfectly drying, it will have a scum formed at the top. Perhaps white lead would be better to use than litharge.

Poppy-oil is from the seeds of the common poppy.

Nut-oil is the oil expressed in the same manner from walnut. It is made drying in the same manner as linseed-oil; and being clearer, is preferable for colourless varnishes.

To make boiled linseed-oil colourless, take three or four gallons of oil; add to it about two quarts of fine clear sand, and three or four gallons of boiling water: agitate it for half an hour, separate the oil, and repeat the process with fresh water.

Oil of turpentine is produced by the distillation of common turpentine: the residuum is rosin.

Copal is a resin produced from certain trees in New Spain. The best is the clearest, and such as will glaze a hot tobacco-pipe without blistering.

Amber (Karabe, *succinum*) is a substance (but whether vegetable or animal is not quite determined), found upon the sea-shores of Polish Prussia. It has been by some thought a resin from trees; by others, a fossil; by others, the indurated excrement of the whale.

Mastic is a resin produced from a small tree called the lentisk, growing in the isle of Chio. The bark is cut, and the juice exudes.

Sandarac is a resin produced in the same way from a species of juniper, growing on the coast of Africa.

Lac, gum-lac, seed-lac, is produced on certain trees of the fig kind in the mountainous parts of the East Indies, by the perforation of insects in the bark. It has been thought by some a kind of wax, produced by the insects themselves.

Turpentine is collected in the Greek isles, by making an incision in the fir-trees: the juice is turpentine. Venice (Chian) turpentine is brought over in large earthen jars.

Common rosin, the residuum of turpentine, after distilling it to obtain the essential oil.

Dragon's blood, a resin of a red colour produced from certain trees in the East Indies and Maderia, and the Canary Islands.

Gum-elemi, a resin, the produce of trees growing in the East Indies and Brazil.

Asphaltum, Jew's pitch. This is a native bitumen found in various parts of the world, of a blackish-brown colour.

Common pitch is the residuum after the distillation of tar.

Elastic gum, a substance from the East Indies and the Brazils, having all the properties of inspissated bird-lime, or of the juice of the misseltoe.

It dissolves in petroleum and oil of turpentine.

General Observations on making Varnishes of all Kinds.

1st. As the substances that form varnishes are extremely inflammable, they ought only to be made in a brick or stone room with a floor of the same materials. They should be cautiously kept from a fire that flames; nor should a lighted candle come near them, for the vapour, particularly of oil of turpentine and spirit of wine, will catch fire at some distance by means of flame of any kind. The operator should always have by him a woollen cloth or small blanket in a tub of water to cover the vessel containing the ingredients in case of their taking fire. They can only be put out by thus excluding the air.

2d. The substances should be freed, as much as possible, from impurities of every kind, particularly sandarac, and preserved free from dust. The utmost cleanliness in and about the vessels is essentially necessary to good colour and transparency.

3d. The substances, after being broken into pieces, freed from impurities and heterogeneous substances, should be put by themselves into the melting-pot. If reduced to powder or very small pieces, they stick to the sides of the pot, and burn and hurt the colour.

4th. All the resins should be kept in vessels well stopt and closed from dust. So of the oils and spirit.

5th. When the varnish is made, it should be left some time for the dregs to settle: then be poured off clear, and then be filtered through silk or lawn.

6th, For goods that are not to be exposed to the heat of the sun,

the spirit varnishes will answer: but as sandarac and mastic will melt in the sun, the oil varnishes of copal and amber are the most proper.

7th, Glazed earthen vessels are better than iron: copper is soluble in oil, and therefore is not to be used. The most scrupulous cleanliness is necessary to success.

Of Varnishes with Spirit of Wine.

Copal-spirit Varnish.—This receipt is kept a great secret by Mr. Henry of Rochester, and the Sieur Watin of Paris, but the following is the real receipt:

Dissolve half an ounce of camphor in a pint of alkohol, or spirits of wine; put it into a circulating glass, and add four ounces of copal, in small pieces; set it in a sand-heat so regulated that the bubbles may be counted as they rise from the bottom; and continue the same heat till the solution is completed.

Camphor acts more powerfully upon copal than any other substance. If copal is finely powdered, and a small quantity of dry camphor rubbed with it in the mortar, the whole becomes in a few minutes a tough coherent mass. The process above described will dissolve more copal than the menstruum will retain when cold. The most economical method will therefore be, to set the vessel which contains the solution by for a few days; and when it is perfectly settled, pour off the clear varnish, and leave the residuum for a future operation.

This is a very bright solution of copal: it is an excellent varnish for pictures, and may perhaps be found to be an improvement in fine japan works, as the stoves used in drying those articles may drive off the camphor entirely, and leave the copal pure and colourless upon the work.

Copal will dissolve in spirit of turpentine, by the addition of camphor, with the same facility, but not in the same quantity, as in alkohol.

We have made it, by dissolving copal in a warm place, in any of the following essential oils: bergamotte, lavender, orange, lemon, rosemary, of which the last is the cheapest; dilute it with twice the quantity of highly rectified spirit of wine. If the oil of rosemary is much adulterated with oil of turpentine, it will not succeed. Oil of turpentine precipitates the copal; but by twelve hours digestion (in a small retort with a lamp heat) of oil of turpentine on copal, we succeeded in making a perfectly colourless varnish.

Colourless Spirit Varnish of Mastic and Sandarac.

To one quart of rectified spirit add two ounces of mastic in drops, and six ounces of sandarac; when well dissolved, add four ounces of pure Venice turpentine.

If it is wanted to be harder, substitute two ounces of gum-lac, half an ounce of gum-elemi, and two ounces of clear white rosin instead of the mastic and turpentine. But the colour will not be so good. The first is proper for toilet-boxes, &c. the last for cane, chairs, furniture, &c. which are much handled

Varnish for Violins and Musical Instruments.

Spirit of wine one quart, sandarac four ounces, gum-lacca and mastic, each two ounces, gum-elemi one ounce; when all is melted, add two ounces of turpentine.

Gold-colour Varnish.

Bruise separately four ounces of lacca, as much gamboge, as much dragon's-blood, as much annatto, and one ounce of saffron. Put each of these into a quart of spirit of wine. Digest them in the sun or in a moderate heat for a fortnight, mix them with clear varnish of sandarac according to the tint you want. Four ounces of aloes dissolved in a quart of spirit will also be a good addition to the above ingredients, and give you more command over the tint you may require.

General Observations on Spirit Varnishes.

1. A water-bath is the proper heat for spirit varnishes. A sand-bath is to be too hot, and embers or coals dangerous.

When the water once boils, keep it boiling till the substances are dissolved. This you will find by stirring it with a glass, or white wood spatula, or a tobacco-pipe. By dissolving salt in the water, you may increase the heat. When your substances are not quite dissolved, never put them on the fire a second time to finish the solution.

Never fill the vessels but about three parts full.

2. Gum-elemi gives consistence to the varnish, but should be used in small proportions. Brilliancy is given by the Venice and Chio turpentine.

3. The turpentine should always be melted separately, when the substances are dissolved: it should be melted in a small quantity of spirit of wine, and then added. After the turpentine is added, give the water-bath six or eight boils, and then take it off, and strain it through a very fine sieve or fine linen. It will be still clearer by standing and repose.

4. The general proportion of sandarac is about ten or twelve ounces to a quart of spirit, and so of the other gums: if others are substituted, the sandarac must be proportionably diminished. The spirits of wine should fire gunpowder.

5. If you want red or black varnishes, dragon's-blood and vermilion, Jew's-pitch and lamp-black, will answer your purpose.

6. Seed-lac makes harder varnish than shell-lac; about ten ounces to the quart is enough.

Oil Varnishes.—General Observations on Oil Varnishes.

1. Copal and amber are the two principal substances for oil varnishes; as each of them possesses the property of making a hard and transparent varnish, they need not be mixed; but copal should be reserved for the lighter coloured varnishes. Amber, however, is tougher than copal, and a little of it certainly improves copal varnish, if the tinge of colour is no objection.

2. It requires a stronger fire to dissolve copal and amber when mix-

ed with oil, than alone; a strong heat hurts the colour. Melt therefore these resins by themselves, broken into small pieces; employ no more heat than is necessary to melt them; when melted, add to them the hot linseed oil by degrees, stirring as you pour it in; then give a few boilings to incorporate the whole.

3. If you have more than one resin to add, melt the hardest first, otherwise the most fusible will burn before the other is melted.

4. A sand-bath, or bright coals that do not flame, is the proper heat for oil varnishes: but give no more heat than is barely necessary to melt them.

5. The vessels should be glazed earthenware with a cover; and new ones used, for copal varnish especially, every time.

6. When the oil and the resin are incorporated and well stirred together, add your hot oil of turpentine; this should be about double the quantity of the oil employed; but the oil should not be boiling hot when the turpentine is poured in, otherwise it may catch fire. Stir it.

7. Filter or strain the varnish; then let it rest at least forty-eight hours. The sediment will do for a coarser or more coloured varnish of the same kind: the oil mixed with the sediment will tarnish the colour at the second melting.

Copal Varnish.

Melt slowly one pound of copal; add half a pint of boiling drying oil: when incorporated, add one pint of oil of turpentine made hot. You may add from half a pint to three pints of boiling drying oil, according to the consistence required.

Another.

Melt in a perfectly clean vessel, by a very slow heat, a pound of clear copal: to this add from one to two quarts of drying linseed oil; when the materials are thoroughly mixed, remove the vessel from the fire, and keep constantly stirring it till most of the heat is gone: then add one pound of oil of turpentine. Strain the varnish through a piece of close linen, and keep it for use. The older it is, the more drying does it become.

Another.

M. Carendeffex, formerly of St. Domingo, and at present resident at New York, finds that an ounce of good sulphuric æther, and an ounce of copal in gross powder, mixed together in a well stopped bottle, and placed in a moderate sand-heat or water-bath, from a perfect solution. Mr. C. remarks, that the solution, though not very cheap, affords a fine and brilliant varnish, and the process is so easy as to be repeated by any person though of very moderate skill.

Gold-colour Varnish, or Lacker.

Take eight ounces of amber, two ounces of lacca; melt them; add eight ounces of drying oil: then add oil of turpentine coloured with gamboge, annatto, saffron, and dragon's-blood, according to the tinge you want.

To dissolve Gum-copal in Oil of Turpentine.

Whatever quantity is to be dissolved, should be put into a glass vessel capable of containing at least four times as much, and it should be high in proportion to its breadth.

Reduce two ounces of copal to small pieces, and put them into a proper vessel. Mix a pint of oil of turpentine with one-eighth part of spirit of sal ammoniac; shake them well together; put them to the copal; cork the glass, and tie it over with a string or wire, making a small hole through the cork. Set the glass in a sand heat so regulated, as to make the contents boil as quickly as possible, but so gently, that the bubbles may be counted as they rise from the bottom. The same heat must be kept up exactly till the solution is complete.

It requires the most accurate attention to succeed in this operation. After the spirits are mixed, they should be put to the copal, and the necessary degree of heat be given as soon as possible. It should likewise be kept up with the utmost regularity. If the heat abates; or if the spirits boil quicker than is directed, the solution will immediately stop, and it will afterwards be in vain to proceed with the same materials; but if properly managed, the spirit of sal ammoniac will be seen gradually to descend from the mixture, and attack the copal, which swells and dissolves, except a very small quantity which remains undissolved.

Black Japan.

Melt eight ounces of amber; melt (separately from the amber) four ounces of asphaltum, and four ounces rosin: when melted, add eight ounces of boiling oil, and then sixteen ounces of oil of turpentine; then stir in from half an ounce to one ounce lamp-black, and give it another boil or two.

Common Varnish.

One pound of rosin, one ounce gum-elemi, eight ounces drying oil, and sixteen ounces oil of turpentine.

Varnishes with Turpentine alone.

Oil of turpentine will dissolve any of these resins, except copal and amber; but it does not make so good varnish as when mixed with boiled oil.

Common Turpentine Varnish

Is frequently made by dissolving one pound of turpentine, or about ten ounces of rosin, in oil of turpentine alone.

Elastic Gum Varnish.

Cut the gum into small pieces, and digest it with thirty-two parts of pure oil of turpentine for twenty-four hours in a warm place. Rosemary, lavender, and other essential oils also dissolve it. So does nitric ether. If softened by boiling in water, or still more in a solution of alum, it may be joined.

Varnishes of Gums.

Gum-tragacanth and gum-arabic may be dissolved in water; or the first in brandy. *Ichthyocolla* (isinglass) is best dissolved in brandy or whiskey.

Elastic Gum.

Size—From diluted glue: from white leather cuttings.
Fish Size—Boiled eel skins.

Martin's Copal Varnish.

In a large gallon earthen pot, with a cover like a chocolate pot, melt four ounces of Chio turpentine: when fluid, pour in eight ounces of amber powdered; set it on the fire a quarter of an hour. Take off the pot; add to it one pound of pounded copal, four or more of turpentine, and one gill of warm oil of turpentine. Increase the heat a little; when it has been on the fire half an hour, take it off, stir the ingredients, adding two ounces of the finest and whitest colophony or rosin. Set it again on the fire, and increase the heat till the whole is quite fluid. Remove the pot; let the heat subside a little; have ready twenty-four ounces (about one pint and a quarter) of drying linseed oil, poppy, or nut-oil; pour it boiling hot by degrees into your gums and stir them well. When mixed, set it again on the fire, stirring it till it boils up; then take it off, and add a quart of turpentine made hot; stir and give it one boil more; then add another pint of turpentine made hot; stir it well, give it one more boil, and it is enough. Strain it; if thicker than linseed oil, thin it with oil of turpentine. Let it stand a month before it is used. It should be made in an open yard, for the frequent practice is very unwholesome.

Great danger will attend the addition of copal, as the same heat which would be required to dissolve the copal would volatilize the turpentine, and take fire if the vapour were directed to the flame.

Black Varnish for Coaches and Iron-work.

This varnish is composed of asphaltum, resin and amber, melted separately, and afterwards mixed; the oil is then added, and afterwards the turpentine, as directed above. The usual proportions are, twelve ounces of amber, two of resin, two of asphaltum, six of oil, and twelve of turpentine.

A Varnish for rendering Silk water and air-tight.

To render the linseed-oil drying, boil it with two ounces of sugar of lead, and three ounces of litharge, for every pint of oil, till the oil has dissolved them; then put a pound of bird-lime, and half a pint of the drying oil, into a pot of iron or copper, holding about a gallon; and let it boil gently over a slow charcoal fire, till the bird-lime ceases to crackle; then pour upon it two pints and a half of drying oil, and boil it for about an hour longer, stirring it often with an iron or wooden spatula. As the varnish in boiling swells much, the pot should be re-

moved from the fire, and replaced when the varnish subsides. While it is boiling, it should be occasionally examined, in order to determine whether it has boiled enough. For this purpose, take some of it upon the blade of a large knife, and after rubbing the blade of another knife upon it, separate the knives; and when, on their separation, the varnish begins to form threads between the two knives, it has boiled enough, and should be removed from the fire. When it is almost cold, add about an equal quantity of spirits of turpentine; mix both well together, and let the mass rest till the next day; then having warmed it a little, strain and bottle it. If it is too thick, add spirits of turpentine. This varnish should be laid upon the stuff when perfectly dry, in a luke-warm state; a thin coat of it upon one side, and, about twelve hours after, two other coats should be laid on, one on each side; and in twenty-four hours the silk may be used.

Mr. Blanchard's Varnish for Air-balloons.

Dissolve elastic gum (Indian-rubber), cut small, in five times its weight of spirits of turpentine, by keeping them some days together; then boil one ounce of this solution in eight ounces of drying linseed-oil for a few minutes, and strain it. Use it warm.

Amber Varnish.

Melt eight ounces of Chio turpentine, pour in one pound of powdered amber by degrees, stirring it all the while; set it on the fire for half an hour, then add two ounces of white rosin; stop the cover close, and increase the fire till the whole is melted. To this add one pound of hot drying oil; and then by degrees a quart of oil of turpentine. Amber can only be dissolved clear, by melting it with some less glutinous gum. Same process for copal varnish.—Dom. Enc. vol. v. (Philadelphia) p. 233.

Varnish for coloured Drawings and Prints.

Take of Canada balsam one ounce, spirit of turpentine two ounces; mix them together. Before this composition is applied, the drawing or print should be sized with a solution of isinglass in water; and when dry, apply the varnish with a camel's-hair brush.

To varnish plaster Casts or Models.

Take about a quarter of an ounce avoirdupoise of the finest white soap; grate it small, and put it into a new glazed earthen vessel, with an English pint of water; hold it over the fire till the soap is dissolved, then add the same quantity of bleached wax cut into small pieces: as soon as the whole is incorporated, it is fit for use.

Mode of application.—Dry the model well at the fire, suspend it by a thread, and dip it in the varnish; take it out, and a quarter of an hour after dip it in again; let it stand for six or seven days, then, with a bit of muslin rolled softly round your finger, rub the model gently, and this will produce a brilliant gloss; but this part of the operation must be done with great care and a light hand, as the coat of varnish is thin.

Another Way.

Take skim milk, from which the cream has been carefully taken off, and with a camel's hair pencil lay over the cast till it holds out, or will imbibe no more; shake or blow off any that remains on the surface, and lay it in a place free from dust; and when it is dry, it will look like polished marble.

N. B. This last mode answers equally well with the former, but will not resist the weather.

Varnish for Earthen-ware.

To make it white, glass and soda in equal proportion must be pounded together, very fine, carefully sifted, and well mixed. The mixture must next be exposed to a strong heat till it is rendered very dry. It is after that to be put into vessels which have been already baked; it will then be melted, and the varnish is made. It may be applied in the usual manner.

French soft Varnish for Engravers.

One ounce of virgin's wax, one ounce of asphaltum or Greek pitch, half an ounce of common pitch, and a quarter of an ounce of Burgundy pitch.

N. B. The celebrated Vivares, the landscape engraver, always used this varnish, in preference to any other.

Varnish for Furniture.

To one part of virgin's white wax, add eight parts of oil of petroleum; lay a slight coat of this mixture on the wood with a badger's brush, while a little warm; the oil will then evaporate, and leave a thin coat of wax, which should afterwards be polished with a coarse woollen cloth.

A Varnish for Toilet Boxes, Cases, Fans, &c.

Dissolve two ounces of gum-mastic, and eight ounces of gum-sandarac, in a quart of alkohol; then add four ounces of Venice turpentine.

Preparation of the true Copal Varnish.

Take two parts of gum copal, reduced to a fine powder; wash it repeatedly in water, to free it from the woody fibres; then introduce it into a flask, and pour over it four parts of pure oil of rosemary: digest the mixture in a gentle heat for three days, or longer; after which, add as much highly rectified spirits of wine as is deemed necessary, and suffer it to remain undisturbed, until the impurities subside: then decant the varnish.

To make Varnish for Oil Paintings.

According to the number of your pictures, take the whites of the same number of eggs, and to each picture take the bigness of a hazelnut of white sugar-candy, dissolved, and mix it with a tea-spoonful of brandy; beat the whites of your eggs to a froth; then let it settle; take

the clear, put to it your brandy and sugar, and varnish over your pictures with it; this is much better than any other varnish, as it is easily washed off when your pictures want cleaning again.

To make White Varnish.

Dissolve gum-sandarac and gum-mastic in spirits of wine; leave it to settle for two days; then strain it through a linen cloth, let it stand for some time, pour off the clear liquid, and bottle it for use.

Another, by Dr. Withering.

Take of gum-sandarac an ounce and a half; mastic, in drops, half an ounce; gum-elemi, a quarter of an ounce; oil of spike lavender, a quarter of an ounce; put them into a half-pint phial, and fill it up with best spirits of wine. Let it stand in rather a warm place, till all the gums are dissolved, and then pour off the varnish into a clean phial, and it will be ready for use.

A Varnish for preserving Insects, Fruits, &c.

Take one pound of rectified spirits of wine, and two ounces of white amber; add thereto an ounce of white sandarac and white mastic, an ounce and a half of Venice turpentine; digest the whole in balneo mariæ during forty-eight hours, to an entire dissolution: take out the intestines of the insect you have a mind to preserve; lay them for some days in rectified spirits of wine, mixed with clarified sugar-candy; afterwards besmear them with your varnish till they are transparent as glass; in this manner you will preserve them a long time.

This varnish suceeds equally with vegetables and fruits, which never rot or decay when not affected by the exterior air, as has been observed with regard to cherries, which are preserved perfectly well, by besmearing them with melted white wax.

Method of preparing Linseed Oil Varnish.

One pound of well pulverized and sifted litharge, four ounces of finely pounded white vitriol, and one quart of linseed oil. Put these ingredients into an iron pan of such a size that it may be only half full; mix them well together, and boil them till the moisture is evaporated, which may be known by a pellicle being formed on the surface, or by the barrel of a quill bursting when thrust to the bottom of the boiling varnish. Then take it from the fire and pour off the clear liquid, taking care to keep back the thick part, which has deposited itself at the bottom. While boiling, it must be stirred several times round, that the litharge may not fall to the bottom; but stir it constantly, else superfluous litharge will be dissolved, and the varnish become too thick.

The composition of amber varnish consists of half a pound of melted or roasted amber, one pound and a half of linseed oil varnish, and two pounds of turpentine oil. The amber and linseed oil varnish are to be mixed together in a deep cast-iron pan, of such a size as to be only one-third full, and to be kept over a slow fire till the amber is dissolved, which may be known by its swelling up; the operator therefore must

have at hand a large copper, or iron vessel, that the varnish may be held over it in case it should rise above the sides of the pan, and to prevent the loss that would thereby be occasioned.—When the varnish is dissolved, the pan must be taken from the fire; and when the mixture has cooled, the turpentine oil is to be poured into it, continually stirring it. Then let it stand some time, that the coarse undissolved particles may deposit themselves at the bottom; after which pour off the clear varnish, and, having strained it through a piece of linen, put it in bottles for use.

In boiling the varnish, care must be taken that it may not boil over, or catch fire. Should this happen to be case, it must not be extinguished by water; for this mode would occasion such a spattering, that the operator would be in danger of having his face bespattered with the boiling varnish. The best method, therefore, is to cover the vessel in such a manner as to exclude the air, and for this purpose to have at hand a piece of wood, plate of iron, or any thing else that may cover the vessel and extinguish the flame.

Varnish for Pales and coarse Wood Work.

Take any quantity of tar, and grind it with as much Spanish brown as it will bear, without rendering it too thick to be used as a paint or varnish, and then spread it on the pales, or other wood, as soon as convenient, for it quickly hardens by keeping.

This mixture must be laid on the wood to be varnished, by a large brush, or house-painter's tool; and the work should then be kept as free from dust as possible, till the varnish be thoroughly dry. It will, if laid on smooth wood, have a very good gloss, and is an excellent preservative of it against moisture; on which account, as well as its being cheaper, it is far preferable to painting, not only for pales, but for weather-boarding, and all other kinds of wood-work for grosser purposes. Where the glossy brown colour is not liked, the work may be made of a greyish brown, by mixing a small proportion of white lead, or whitening, or ivory black, with the Spanish brown.

To make Gold Varnish.

This ingenious process, which is at present employed throughout Europe, in gilding wooden frames, coaches, and various other articles, and which was formerly used in the preparation of the now old-fashioned leather tapestry, was invented towards the end of the sixteenth century. The composition is as follows:—

Take gum-lac, and having freed it from the filth and bits of wood with which it is mixed, put it into a small linen bag, and wash it in pure water, till the water becomes no longer red, then take it from the bag and suffer it to dry. When it is perfectly dry, pound it very fine, because the finer it is pounded it will dissolve the more readily. Then take four parts of spirits of wine, and one of gum, reduced as before directed, to an impalpable powder, so that for every four pounds of spirits you may have one of gum; mix these together; and, having put them into an alembic, graduate the fire so that the gum may dissolve in the spirits. When dissolved, strain the whole through a strong piece of linen cloth; throw away what remains in the cloth, as of no use, and

preserve the liquor in a glass bottle closely corked. This is the gold varnish which may be employed for gilding any kind of wood.

When you wish to use it, you must, in order that the work may be done with more smoothness, employ a brush made of the tail of a certain quadruped called vari, well known to those who sell colours for painting; and with this instrument dipped in the liquor, wash over gently, three times, the wood which has been silvered. You must however, remember, every time you pass the brush over the wood, to let it dry; for in so doing, your work will be extremely beautiful, and have a resemblance to the finest gold.

Varnish for Drawings, Prints, &c. &c.

Boil four ounces of isinglass, in small pieces, in one quart of brandy or spirits of wine, expose it to the air, and when only warm, wash over the print or drawing (which should be previously mounted), and let it stand till quite dry; then wash it again at a small distance from the fire, or it will blister, which repeat two or three times; then go twice over with the following white varnish: take of gum-sandarac and gum-mastic equal parts; dissolve them in spirits of wine; let them settle two days, then strain through a linen cloth, and pour the clear liquor into a bottle for use.

To make a Lacquer for Brass.

Take eight ounces of spirits of wine, and one ounce of annatto, well bruised; mix this in a bottle by itself; then take one ounce of gamboge, and mix it in like manner, to the same quantity of spirits: also bruised saffron, steeped in spirits, to nearly the same proportion. After this take seed-lac varnish, what quantity you please, and you may brighten it to your mind by the above mixture: if it be too yellow, add a little more from the annatto bottle; and if it be too red, add a little more from the gamboge or saffron bottle; if too strong, add a little spirits of wine, &c. Thus you may temper lacquer or varnish to what degree of perfection you please.

To make Chinese Varnish.

Take of gum-lac in grains four ounces; put it into a strong bottle, with a pound of good spirits of wine, and add about the bulk of a hazel-nut of camphor; allow them to mix in summer in the sun, or in winter on hot embers, for twenty-four hours, shaking the bottle from time to time; pass the whole through a fine cloth, and throw away what remains upon it. Then let it settle for twenty-four hours, and you will find a clear part in the upper part of the bottle, which you must separate gently, and put into another phial, and the remains will serve for the first layers.

Varnish to prevent the Rays of the Sun from passing through the Glasses of Windows.

Pulverize gum-tragacanth, and put it to dissolve for twenty-four

hours in whites of eggs well beaten. Lay a coat of this on the panes of your windows with a soft brush, and let it dry.

Seed-Lac Varnish.

Take spirit of wine one quart; put it in a wide-mouthed bottle, and add thereto eight ounces of seed-lac, which is large grained, bright, and clear, free from dirt and sticks: let it stand two days or longer, in a warm place, often shaking it; strain it through a flannel into another bottle, and it is fit for use.

A Varnish for Wainscot, Cane Chairs, &c.

Dissolve in a quart of spirits of wine eight ounces of gum-sandarac, two ounces of seed-lac, and four ounces of resin; then add six ounces of Venice turpentine. If the varnish is to produce a red colour, more of the lac and less of sandarac should be used, and a little dragon's blood should be added. This varnish is very strong.

A Varnish for Violins and other Musical Instruments.

Put four ounces of gum-sandarac, two ounces of lac, two ounces of gum-mastic, one ounce of gum-elemi, into a quart of alkohol, and hang them over a slow fire till they are dissolved; then add two ounces of turpentine.

Varnish for employing Vermilion for painting Equipages.

Dissolve in a quart of alkohol six ounces of sandarac, three ounces of gum-lac, and four ounces of resin; afterwards add six ounces of the cheapest kind of turpentine: mix it with a proper quantity of vermilion when it is to be used.

Shell-Lac Varnish.

Take one quart of spirits of wine, eight ounces of the thinnest and most transparent shell-lac, which, if melted in the flame of a candle, will draw out in the longest and finest hair: mix and shake these together, and let them stand in a warm place for two days, and it is ready for use. This varnish is softer than that which is made from seed-lac, and therefore is not so useful; but may be mixed with it for varnishing wood, &c.

CHAP. X.

CEMENTS.

Cements require to be of various compositions, according to the substances to which they are applied, and whether they are to be exposed to heat and moisture.

Common Glue.—Common glue is formed by extracting the gelatinous part of cuttings or scraps of coarse leather, or the hides of beasts. It is never manufactured but in the large way, and therefore not necessary to be described here.

Isinglass Glue.—Isinglass glue is made by dissolving beaten insinglass in water by boiling, and, having strained it through a coarse linen cloth, evaporating it again to such a consistence, that being cold, the glue will be perfectly hard and dry.

This cement is improved by dissolving the isinglass in any proof spirit by heat, or by adding to it, when dissolved in water, an equal quantity of spirits of wine.

It is still further improved by adding to the isinglass, previous to its solution in spirits, one-third of its weight of gum-ammoniac. Expose the mixture to a boiling heat until the isinglass and gum are dissolved, and until a drop of the composition becomes stiff instantly as it cools. It will, at any future time, melt with a degree of heat little exceeding that of the human body; and, in consequence of so soon becoming stiff on cooling, forms a very valuable cement for many purposes, particularly for the very nice and delicate one of fixing on the antennæ, legs, &c. of insects in cabinets of natural history. The easy melting of this cement is no objection to its use in cases where the articles themselves may afterwards be exposed to moderate heat; for it owes this property only to the presence of the spirit, which evaporates soon after it has been applied. When used to join broken glass or china, the pieces to be joined should be previously warmed. Immersion in hot water will give them a sufficient degree of heat. Wipe off the water before applying the cement, which may be laid on with a pencil; then press the pieces together, binding them with a string or bit of soft wire, if necessary.

This isinglass glue is far preferable to common glue for nice purposes, being much stronger, and less liable to be softened either by heat or moisture.

Parchment Glue.—Take one pound of shreds of parchment, or vellum, and boil it in six quarts of water till the quantity be reduced to one quart; strain off the fluid from the dregs, and then boil it again till it be of the consistence of glue.

The same may be done with glovers' cuttings of leather, which are dressed with alum instead of being tanned; this will make a colourless glue.

A good Glue for Sign Boards, or any thing that must stand the Weather.—Melt common glue with water to a proper consistence; then add one-eighth of boiled linseed-oil, dropping it into the glue gently, and stirring it all the time.

A very strong glue is made by adding some powdered chalk to common glue.

Another that will resist water is made by adding half a pound of common glue to two quarts of skimmed milk.

Preparation of Lip Glue for Cementing Paper, Silk, thin Leather, &c.—Take of isinglass glue and parchment glue each one ounce; of sugar-candy and gum-tragacanth each two drachms; add to them an ounce of water, and boil the whole together till the mixture appears, when cold, of the proper consistence of glue. Then form it into small rolls, or any other figure that may be most convenient.

This glue may be wet with the tongue, and rubbed on the edges of the paper, silk, &c. that are to be cemented, which will, on their being laid together, and suffered to dry, unite as firmly as any other part of the substance.

Lapland Glue.—The bows of the Laplanders are composed of two pieces of wood glued together: one of them of birch, which is flexible, and the other of fir of the marches, which is stiff, in order that the bow when bent may not break, and that when unbent it may not bend. When these two pieces of wood are bent, all the points of contact endeavour to disunite themselves; and to prevent this, the Laplanders employ the following cement: they take the skins of the largest perches (it is probable that eel-skins would answer the same purpose), and having dried them, moisten them in cold water until they are so soft that they may be freed from the scales, which they throw away. They then put four or five of these skins in a rein-deer's bladder, or they wrap them up in the soft bark of the birch-tree, in such a manner that water cannot touch them, and place them thus covered into a pot of boiling water, with a stone above them to keep them at the bottom. When they have boiled about an hour, they take them from the bladder or bark, and they are then found to be soft and viscous. In this state they employ them for glueing together the two pieces of their bows, which they strongly compress and tie up till the glue is well dried. These pieces never afterwards separate.

A Glue from Cheese.—Take skimmed-milk cheese, free from the rind, cut it into slices, and boil it in water, stirring it with a spoon until it be reduced to a strong glue, which does not incorporate with water. Then throw away the hot water; pour cold water over the glue, and knead it afterward in warm water, subjecting it to the same process several times. Put the warm glue on a grinding stone, and knead it with quick lime until you have a good glue. When you wish to use this glue you must warm it; if it be employed cold it is not so strong, but it may also be used in that manner. This glue is insoluble in water as soon as it is dry, and it becomes so in forty-eight hours after it has been applied. It may be used for glueing wood, and for cementing marble and broken stone and earthen-ware. Baits for catching fish may also be made of it. Fish are very fond of it, and it resists water.

Jewellers' Cement.—In setting precious stones, pieces are sometimes broken off by accident. In such cases, they often join the pieces so correctly, that an inexperienced eye cannot discover the stone to have been broken. They employ for this purpose a small piece of gum-mastic applied between the fragments, which are previously heated sufficiently to enable them to melt the interposed gum. They are then pressed together to force out the redundant quantity of gum.

Turkey Cement for joining Metals, Glass, &c.—Dissolve five or six

bits of mastic, as large as peas, in as much spirits of wine as will suffice to render it liquid: in another vessel dissolve as much isinglass (which has been previously soaked in water till it is swollen and soft) in brandy or rum, as will make two ounces by measure of strong glue; and add two small bits of gum-galbanum or ammoniacum, which must be rubbed or ground till they are dissolved; then mix the whole with a sufficient heat; keep it in a phial stopt, and when it is to be used set it in hot water.

A Cement for broken China, Glasses, &c.—Take quick-lime and white of eggs, or old thick varnish; grind and temper them well together, and it is ready for use.

Drying oil and white-lead are also frequently used for cementing china and earthen-ware; but this cement requires a long time to dry. Where it is not necessary the vessels should endure heat or moisture, isinglass glue, with a little tripoli, or chalk, is better. The juice of garlic also forms a strong cement, and the joining can scarcely be perceived.

A Cement for Chemical Glasses that will bear the Fire.—Mix equal quantities of wheat flour, fine powdered Venice glass, pulverized chalk, with half the quantity of fine brick-dust, and a little scraped lint in the whites of eggs: this mixture is to be spread upon a linen cloth, and applied to the crack of the glasses, and should be well dried before they are put into the fire.

A Cement useful for Turners.—Take resin one pound, pitch four ounces; melt these together, and, while boiling hot, add brick-dust, until, by dropping a little upon a stone, you perceive it hard enough; then pour it into water, and immediately make it up in rolls, and it is fit for use.

Another, finer.—Take resin one ounce, pitch two ounces; add red-ochre, finely powdered, until you perceive it strong enough. Sometimes a small quantity of tallow is used, according to the heat of the weather, more being necessary in winter than in summer.

Either of these cements is of excellent use for turners. By applying it to the side of a chuck, and making it warm before the fire, you may fasten any thin piece of wood, which will hold while you turn it; when you want it off again, strike it on the top with your tool, and it will drop off immediately.

A strong Cement for Electrical Purposes.—Melt one pound of resin in a pot or pan over a slow fire; add thereto as much plaster of Paris, in a fine powder, as will make it hard enough, which you may soon know by trial; then add a spoonful of linseed-oil, stirring it all the while, and try if it be hard and tough enough for your purpose; if it is not sufficiently hard, add more plaster of Paris; and if not tough enough, a little more linseed-oil.

This is as good a cement as possible for fixing the necks of globes or cylinders, or any thing else that requires to be strongly fixed; for it is not easily melted again when cold.

Another, softer.—Take resin one pound, bees-wax one ounce; add thereto as much red-ochre as will make it of sufficient stiffness; pour it into water, and make it into rolls, and it is fit for use. This cement is useful for cementing hoops on glasses, or any other mounting of electrical apparatus.

A Cement for Glass Grinders.—Take pitch and boil it; add thereto, and keep stirring it all the while, fine-sifted wood-ashes, until you have it of a proper temper; the addition of a little tallow may be added, as you find necessary.

Another, for small Work.—To four ounces of resin add one-fourth of an ounce of bees-wax, melted together, add four ounces of whitening, made previously red hot. The whitening should be put in while hot, that it may not have time to imbibe moisture from the atmosphere.

Shell-lac is a very strong cement for holding metals, glass, or precious stones, while cutting, turning, or grinding them. The metal, &c. should be warmed to melt it. For fastening ruby cylinders in watches, and similar delicate purposes, shell-lac is excellent.

To solder or cement broken Glass.—Broken glass may be soldered or cemented in such a manner as to be as strong as ever, by interposing between the parts, glass ground up like a pigment, but of easier fusion than the pieces to be joined, and then exposing them to such a heat as will fuse the cementing ingredient, and make the pieces agglutinate without being themselves fused.

A glass for the purpose of cementing broken pieces of flint glass may be made by fusing some of the same kind of glass previously reduced to powder, along with a little red-lead and borax, or with the borax only.

Cement for Derbyshire Spar and other Stones.—A cement for this purpose may be made with about seven or eight parts of resin and one of bees-wax, melted together with a small quantity of plaster of Paris. If it is wished to make the cement fill up the place of any small chips that may have been lost, the quantity of plaster must be increased a little. When the ingredients are well mixed, and the whole is nearly cold, the mass should be well kneaded together. The pieces of spar that are to be joined, must be heated until they will melt the cement, and then pressed together, some of the cement being previously interposed.

Melted sulphur applied to fragments of stones previously heated (by placing them before a fire) to at least the melting point of sulphur, and then joined with the sulphur between, makes a pretty firm and durable joining.

Little deficiencies in the stone, as chips out of corners, &c. may also be filled up with melted sulphur, in which some of the powder of the stone has been melted.

A Cement that will stand against boiling Water, and even bear a considerable Pressure of Steam.—In joining the flanches of iron cylinders, and other parts of hydraulic and steam-engines, great inconvenience is often experienced from the want of a durable cement.

Boiled linseed-oil, litharge, red and white-lead, mixed together to a proper consistence, and applied on each side of a piece of flannel previously shaped to fit the joint, and then interposed between the pieces before they are brought home (as the workmen term it) to their place by the screws or other fastenings employed, make a close and durable joint.

The quantities of the ingredients may be varied without inconvenience, only taking care not to make the mass too thin with oil. It is difficult in many cases instantly to make a good fitting of large pieces of iron work, which renders it necessary sometimes to join and separate the pieces repeatedly, before a proper adjustment is obtained.

When this is expected, the white-lead ought to predominate in the mixture, as it dries much slower than the red. A workman knowing this fact, can be at little loss in exercising his own discretion in regulating the quantities. It is safest to err on the side of the white-lead, as the durability of the cement is no way injured thereby, only a longer time is required for it to dry and harden.

When the fittings will not admit easily of so thick a substance as flannel being interposed, linen may be substituted, or even paper or thin paseboard.

This cement answers well also for joining broken stones, however large. Cisterns built of square stones, put together with this cement, will never leak or want any repairs. In this case, the stones need not be entirely bedded in it: an inch, or even less, of the edges that are to lie next the water need only be so treated; the rest of the joint may to filled with good lime.

Admirable Cement, or Mortar, as made on the Cotswold Hills.—On the Cotswold Hills in Gloucestershire, where lime is dear and sand not to be had, an excellent mortar is prepared at a moderate price. Invention is seldom more successful than when it is prompted by necessity. The scrapings of the public roads over these hills, being levigated limestone, more or less impregnated with the dung and urine of the animals travelling on them, are found to be a most admirable basis for cement. The scrapings alone are frequently used for ordinary walls; and the general proportion, for even the best buildings, is not more than one part lime to three of scrapings. This mortar, of less than ten years standing, has been observed to possess a stone-like tenacity, much firmer than the common stone of the country, and consequently much harder than the stones from which either the basis or the lime was made. The method of preparing this cement is simply by collecting the road scrapings, slaking the lime, and mixing them very thoroughly together; carefully picking out, as the mass is worked over, the stones or other foulnesses which may have been collected. For stone work, this is quite sufficient; for brick work, it might be necessary to pass the materials through a screen or sieve previously to their being united, and made up into mortar. Similar scrapings may be collected wherever limestone is used as a material in making or repairing roads; this admirable mortar can, therefore, readily be prepared in all such places with very little trouble or expence.

Useful Property of common Glue.—Common glue, dissolved with linseed-oil, will resist the weather. The glue should be melted with a very little water, before the oil is added.

To make Size from Potatoes.—One of the beneficial uses of potatoes, not perhaps generally known, is, that the starch of them, quite fresh, and washed only once, may be employed to make size, which, mixed with chalk, and diluted in a little water, forms a very beautiful and good white for ceilings. This size has no smell, while animal size, which putrifies so readily, always exhales a very disagreeable odour. That of potatoes, as it is very little subject to putrefaction, appears, from experience, to be more durable in tenacity and whiteness; and, for white-washing, should be preferred to animal size, the decomposition of which is always accompanied with unhealthy exhalations.

To make Patent Paste.—Boil a quantity of mealy potatoes, and mash them without peeling; then take as many, and one-third more

of raw potatoes, and obtain the starch or flower from them, by grating them into a vessel of water, and reserving only the finer particles. The mashed potatoes are to be diluted, beat up, and passed through a sieve. They are then to be put into a boiler, and, when nearly boiling, the starch produced from the grated potatoes is to be added, and the whole boiled together about twenty minutes, during which time it must be kept carefully stirred: it is then good paste, and is to put into a wide vessel to cool.

Preparation of common Cement for joining Alabaster, Marble, Porphyry, or other Stones.—Take of bees-wax two pounds, and of rosin one pound, melt them, and add one pound and a half of the same kind of matter, powdered, as the body to be cemented is composed of, strewing it into the melted mixture, and stirring them well together, and afterwards kneading the mass in water, that the powder may be thoroughly incorporated with wax and rosin. The proportion of the powdered matter may be varied where required, in order to bring the cement nearer to the colour of the body on which it is employed.

This cement must be heated when applied; as must also the parts of the subject to be cemented together; and care must be taken likewise that they be thoroughly dry.

When this composition is properly managed, it forms an extremely strong cement, which will even suspend a projecting body of considerable weight after it is thoroughly dried and set; and is therefore of great use to all carvers in stone, or others who may have occasion to join together the parts of bodies of this nature.

Melted sulphur applied to fragments of stones previously heated (by placing them before a fire) to at least the melting point of sulphur, and then joined with the sulphur between, makes a pretty firm and durable joining.

Chips out of corners, and similar little deficiences in the stone, may also be filled up with melted sulphur, in which some of the powder of the stone has been mixed; but the stone should be previously heated.

Strong Cement.—To prevent the escape of the vapours of water, spirits, and liquors not corrosive, the simple application of slips of moistened bladder will answer very well for glass, and paper with good paste for metal. Bladder, to be very adhesive, should be soaked some time in water moderately warm till it feels clammy: it then sticks very well: if smeared with white of eggs instead of water, it adheres still closer.

Fire Lute.—For a fire lute, take porcelain clay from Cornwall (not pipe clay), let it be pounded small, and mixed up to the consistence of thick paint, with a solution of two ounces of borax in a pint of hot water. For want of this peculiar kind of clay, slaked quick-lime mixed up in the same manner may be used. This may be kept ready mixed in a covered vessel.

Cold Lute.—Take equal parts, by measure, of the above clay and wheat flour; mix them to a proper consistence with cold water. This is more tenacious than the fire lute, but does not keep so well.

Another.—A very excellent lute for many purposes may be made by beating up an egg, both the white and the yolk, with half its weight of quick-lime in powder. This lute is to be put upon a piece of linen, and applied as usual. It dries slowly, but becomes very compact, and acquires great hardness.

Cement for Iron Flues.—Common salt and sifted wood-ashes, equal parts, made into a paste with water, make a good cement for iron flues, &c. better than most other compositions, and may be applied when the flue is hot or cold. Iron-filings and vinegar will do as well, or rather iron-filings moistened with diluted muriatic acid. These are commonly used for filling up the spaces between cylinders.

Blood Cement for repairing Copper Boilers, &c. &c.—This cement is often used by coppersmiths to lay over the rivets and edges of the sheets of copper, in large boilers, to serve as an additional security to the joinings, and to secure cocks, &c. from leaking; it is made by mixing pounded quick-lime with ox's blood. It must be applied fresh made, as it soon gets so hard as to be unfit for use.

If the properties of this cement were duly investigated, it would be found useful for many purposes to which it has never been yet applied. It is extremely cheap, and very durable.

To restore Cast Iron Furnaces, and Soap Pans, that through Accident or Mismanagement may be cracked.—Take a small clod of fine new lime, slacked, and finely sifted, mix it up with white of eggs, well beaten, till it is of the consistence of pap or soft mortar, then add to it some iron-file dust, and with this composition fill up the inside of the crack (which will be sufficient), raising a little seam or bead upon it, and it will soon become hard and fit for use.

This experiment completely cured a gentleman's furnace which had a crack fourteen inches long, and he has boiled in it three or four days every week since without the least inconvenience or prospect of its being again disunited.

Composition for a Cement to resist the Action of Fire and Water.—Take half a pint of milk, and mix with it an equal quantity of vinegar so as to coagulate the milk. Separate the curds from the whey, and mix the latter with the whites of four or five eggs, after beating them well up. The mixture or these two substances being complete, add sifted quick-lime, and make the whole into a thick paste of the consistence of putty. If this mastic is carefully applied to broken bodies, or to fissures of any kind, and dried properly, it resists water and fire.

A Cement to resist Moisture—May be formed by melting by heat, without water, common glue, with half its weight of rosin; to which must be added some red-ochre, to give it body; it is particularly useful for cementing hones to their frames.

To make Japanese Cement, or Rice Glue.—This elegant cement is made by mixing rice-flour intimately with cold water, and then gently boiling it. It is beautifully white, and dries almost transparent. Papers pasted together by means of this cement will sooner separate in their own substance than at the joining, which makes it extremely useful in the preparation of curious paper articles, as tea-trays, ladies' dressing-boxes, and other articles which require layers of papers to be cemented together. It is, in every respect, preferable to common paste made with wheat-flour for almost every purpose to which that article is usually applied. It answers well, in particular, for pasting into books the copies of writings taken off by copying-machines on unsized silver paper.

With this composition, made with a comparatively small quantity of water, that it may have the consistence similar to plastic clay, models, busts, statues, basso-relievos, and the like, may be formed. When

dry, the articles made of it are susceptible of a high polish: they are also very durable.

The Japanese make quadrille fish of this substance, which so nearly resemble those made of mother-of-pearl, that the officers of our East Indiamen are often imposed upon.

Turkey Cement for joining Metals, Glass, &c.—The jewellers in Turkey, who are mostly Armenians, have a curious method of ornamenting watch-cases, and similar things, with diamonds and other stones, by simply glueing them on. The stone is set in silver or gold, and the lower part of the metal made flat, or to correspond with the part to which it is to be fixed; it is then warmed gently, and the glue applied, which is so very strong that the parts never separate. This glue may be applied to many purposes, as it will strongly join bits of glass or polished steel.

Excellent Cement for broken China—May be made from a mixture of equal parts of glue, white of egg, and white lead.

To prepare a Cement for joining broken Glass, China, Earthen-ware, &c.—Take two ounces of good glue, and steep it for a night in distilled vinegar; boil them together the next day; and having beaten a clove of garlic, with half an ounce of ox-gall, into a soft pulp, strain the juice through a linen cloth, using pressure, and add the same to the glue and the vinegar. Then take gum-sandarac powdered, and turpentine, of each one drachm, and of sarcoal and mastic powdered, each half a drachm, and put them into a bottle, with an ounce of highly rectified spirits of wine. Stop the bottle, and let the mixture stand for three hours in a gentle heat, frequently shaking it. Mix this tincture also with the glue while hot, and stir them well together with a stick or tobacco-pipe, till part of the moisture be evaporated; then take the composition from the fire, and it will be fit for use. When this cement is to be applied, it must be dipped in vinegar, and then melted in a proper vessel with a gentle heat; and if stones are to be cemented, it is proper to mix with it a little powdered tripoli or chalk: or if glass is to be conjoined, powdered glass should be substituted.

For the uniting the parts of broken china, or earthen-ware vessels, as also glass, where the rendering the joint visible is not of consequence, the following composition, which is much more easily prepared, may be substituted for the foregoing:

Take an ounce of Suffolk cheese, or any other kind devoid of fat, grate it as small as possible, and put it, with an equal weight of quicklime, into three ounces of skimmed milk; mix them thoroughly together, and use the composition immediately.

When the broken vessels are for service only, and the appearance is not to be regarded, the joints may be made equally strong with any other part of the glass, by putting a slip of thin paper, or linen, smeared with this cement, over them, after they are well joined together by it. This method will make a great saving in the case of glasses employed for chemical, or other similar operations.

A cement of the same nature may be made by tempering quicklime with the curd of milk, till it be of a due consistence for use. The curd, in this case, should be as free as possible from the cream or oil of the milk. On this account it should be made of milk from which the cream has been well skimmed off, or the kind of curd commonly sold in the markets, made of whey, and the milk from which butter has

been extracted, commonly called butter-milk. This cement should be used in the same manner as the preceding, and they may be applied to stones, marble, &c. with equal advantage as the compound one above given, and is much more easy and cheaply prepared.

To stop cracks in Glass Vessels.—The cracks of glass vessels may be mended, by daubing them with a suitable piece of linen over with white of egg, strewing both over with finely powdered quicklime, and instantly applying the linen closely and evenly.

Cement for preserving Wood and Brick.—This composition is formed of the following materials, viz. mineral or coal tar, pulverized coal, (charcoal is esteemed the best) and fine well-slaked lime; the coal and lime to be well mixed together, proportioned at about four-fifths coal, and one-fifth lime; the tar to be heated, and while hot, thickened with the mixture of coal and lime, until it becomes so hard that it may be easily spread upon the surface of a board, and not run when hot. Turpentine or pitch will answer nearly as well as tar, and plaster of Paris will answer instead of lime; to be used in the same manner, and in about the same proportions. The cement must be applied warm, and is found to be used easiest with a trowel.

Cement for Wood or Paper.—Dissolve some isinglass in a small quantity of gin or proof spirit, by a very gentle heat; and preserve it in a bottle for use.

Another.—Dissolve, isinglass two parts, and gum arabic, in like manner with the preceding, and keep it in a bottle for use.

Another Cement that will stand the action of boiling Water and Steam.—This cement, which is preferable even to the former for steam engines, is prepared as follows:

Take two ounces of sal ammoniac, one ounce of flowers of sulphur, and sixteen ounces of cast iron filings or borings. Mix all well together by rubbing them in a mortar, and keep the powder dry.

When the cement is wanted for use, take one part of the above powder, and twenty parts of clean iron borings or filings, and blend them intimately by grinding them in a mortar. Wet the compound with water, and when brought to a convenient consistence, apply it to the joints with a wooden or blunt iron spatula.

By a play of affinities, which those who are at all acquainted with chemistry will be at no loss to comprehend, a degree of action and reaction takes place among the ingredients, and between them and the iron surfaces, which at last causes the whole to unite as one mass. In fact, after a time, the mixture and the surfaces of the flanches become a species of pyrites (holding a very large proportion of iron), all the parts of which cohere strongly together.

Flour Paste.—Flour paste for cementing, is formed principally of wheaten flour, boiled in water till it be of a glutinous or viscid consistence.

It may be prepared of these ingredients simply for common purposes, but when it is used by book-binders, or for paper hangings, it is usual to mix with the flour a fifth or sixth of its weight of powdered alum; and where it is wanted still more tenacious, gum arabic, or any kind of size, may be added.

Of Sizes.—Common size is manufactured in the same manner, and generally by the same people. as glue. It is indeed glue left in a moister state, by discontinuing the evaporation before it is brought to a

dry consistence, and therefore further particulars respecting the manufacture of it are needless here.

Isinglass size may also be prepared in the manner above directed for the glue, by increasing the proportion of the water for dissolving it. And the same holds good of parchment size.

CHAP. XI.

TANNING.

Tanning is the art of converting the raw skin of animals into leather. The skin is composed chiefly of two parts; a thin, white, elastic layer on the one side, which is called the epidermis or cuticle, and a much thicker layer composed of a great many fibres closely interwoven, and disposed in different directions. This is called the cutis, or true skin.

The epidermis is that part of the skin which is raised in blisters. It is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity. It is totally insoluble in water and alkohol: pure fixed alkalies dissolve it completely, as does lime likewise, though slowly.

When a portion of cutis is macerated for some hours in water, and agitation and pressure are employed to accelerate the effect, the blood and all the extraneous matter with which it was loaded are separated from it, while its texture remains unaltered. On evaporating the water employed, a small quantity of gelatine may be obtained. No subsequent maceration in cold water has any further effect; the weight of the cutis is not diminished, and its texture is not altered; but if it be boiled in a sufficient quantity of water, it may be completely dissolved, and the whole of it, by evaporating the water, obtained in the state of gelatine.

It was mentioned, when treating of chemistry, that gelatine with tannin, or the tanning principle of vegetables, formed a combination, which is insoluble in water. Upon this depends the art of making leather; the gelatinous part of the skin combining with the tannin of the bark usually employed.

The process which has long been used in this country is as follows: The leather tanned in England consists chiefly of three sorts, known by the name of butts or backs, hides, and skins. Butts are generally made from the stoutest and heaviest ox hides, and are managed as follows: after the horns are taken off, the hides are laid smooth in heaps for one or two days in the summer, and for five or six in the winter; they are then hung on poles, in a close room called a smoke-house, in which is kept a smouldering fire of wet tan; this occasions a small degree of putrefaction, by which means the hair is easily got off, by spreading the hide on a sort of wooden horse or beam, and scraping it with a crooked knife. The hair being taken off, the hide is thrown into a pit or pool of water, to cleanse it from the dirt, &c. which being done, the hide is again spread on the wooden beam, and the grease, loose flesh, extraneous filth, &c. carefully scrubbed out or taken off; the

hides are then put into a pit of strong liquor, called ooze, prepared in pits kept for the purpose, by infusing ground bark in water; this is termed colouring; after which they are removed into another pit called a scowering, which consists of water strongly impregnated with vitriolic acid, or with a vegetable acid prepared from rye or barley. This operation (which is called raising), by distending the pores of the hides, occasions them more readily to imbibe the ooze, the effect of which is to combine with the gelatinous part of the skin, and form with it leather. The hides are then taken out of the scowering, and spread smooth in a pit commonly filled with water, called a binder, with a quantity of ground bark strewed between each. After laying a month or six weeks, they are taken up; and the decayed bark and liquor being drawn out of the pit, it is filled again with strong ooze, when they are put in as before, with bark between each hide. They now lie two or three months, at the expiration of which the same operation is repeated; they then remain four or five months, when they again undergo the same process, and after being three months in the last pit, are completely tanned; unless the hides are so remarkably stout as to want an additional pit or layer. The whole process requires from eleven to eighteen months, and sometimes two years, according to the substance of the hide, and discretion of the tanner. When taken out of the pit to be dried, they are hung on poles, and after being compressed by a steel pin, and beat out smooth by wooden hammers, called battes, the operation is complete; and when thoroughly dry, they are fit for sale. Butts are chiefly used for the soles of stout shoes.

The leather which goes under the denomination of hides, is generally made of cow hides, or the lighter ox hides, which are thus managed. After the horns are taken off, and the hides washed, they are put into a pit of water, saturated with lime, where they remain a few days; when they are taken out, and the hair scraped off on a wooden beam, as before described; they are then washed in a pit, or pool, of water; and the loose flesh, &c. being taken off, they are removed into a pit of weak ooze, where they are taken up, and put down (which is technically termed handling) two or three times a day, for the first week; every second or third day they are shifted into a pit of fresh ooze, somewhat stronger than the former; till at the end of a month or six weeks they are put into a strong ooze, in which they are handled once or twice a week with fresh bark for two or three months. They are then removed into another pit, called a layer, in which they are laid smooth, with bark ground very fine, strewed between each hide. After remaining here two or three months, they are generally taken up, when the ooze is drawn out, and the hides put in again with fresh ooze and fresh bark, where, after lying two or three months more, they are completely tanned; except a few very stout hides, which may require an extra layer: they are then taken out, and hung on poles, and being hammered and smoothed by a steel pin, are, when dry, fit for sale. These hides are called crop hides; they are from ten to eighteen months in tanning, and are used for the soles of shoes.

Skins are the general term for the skins of calves, seals, hogs, dogs, &c. These, after being washed in water, are put into lime pits, as before mentioned, where they are taken up and put down every third or fourth day, for a fortnight or three weeks, in order to destroy the epidermis of the skin. The hair is then scraped off, and the excrescences being

removed, they are put into a pit of water impregnated with pigeon dung, called a grainer, forming an alkaline ley, which in a week or ten days soaking out the lime, grease, and saponaceous matter (during which period they are several times scraped over with a crooked knife, to work out the dirt and filth), softens the skins, and prepares them for the reception of the ooze. They are then put into a pit of weak ooze, in the same manner as the hides, and being frequently handled, are by degrees removed into a stronger, and still stronger liquor, for a month or six weeks, when they are put into a very strong ooze, with fresh bark ground very fine, and at the end of two or three months, according to their substances, are sufficiently tanned: when they are taken out, hung on poles, dried, and are fit for sale. These skins are afterwards dressed and blacked by the curriers, and are used for the upper leathers of shoes, boots, &c.

The lighter sort of hides, called dressing hides, as well as horse hides, are managed nearly in the same manner as skins; and are used for coachwork, harness work, &c.

As the method of tanning above described, and all others in general use, are extremely tedious and expensive in their operation, various schemes at different times have been suggested to shorten the process, and lessen the expence.

Much light has been thrown by modern chemists upon the theory of tanning, though it does not appear that any considerable improvements have been made in the practice of this art. M. Seguin, in France, has particularly distinguished himself by his researches on this subject, and much improved the art in his country.

In 1795, Mr. William Desmond obtained a patent for practising Seguin's method in England. He obtained the tanning principle, by digesting oak bark or other proper material in cold water, in an apparatus nearly similar to that used in the saltpetre works. That is to say, the water which has remained upon the powdered bark for a certain time, in one vessel, is drawn off by a cock, and poured upon fresh tan. This is again to be drawn off, and poured upon other fresh tan; and in this way the process is to be continued to the fifth vessel. The liquor is then highly coloured, and marks from six to eight degrees upon the hydrometer for salts. This he calls the tanning lixivium.

The criterion for ascertaining its strength is the quantity of the solution of gelatine which a given quantity of it will precipitate. Isinglass is used for this purpose, being entirely composed of gelatine. And here it may be observed, that this is the mode of ascertaining the quantity of tanning principle in any vegetable substance, and consequently how far they may be used as a substitute for oak bark.

The hides, after being prepared in the usual way, are immersed for some hours in a weak tanning lixivium of only one or two degrees; to obtain which, the latter portions of the infusions are set apart, or else some of that which has been partly exhausted by use in tanning. The hides are then to be put into a stronger lixivium, where, in a few days, they will be brought to the same degree of saturation with the liquor in which they are immersed. The strength of the liquor will by this means be considerably diminished, and must therefore be renewed. When the hides are by this means completely saturated, that is to say, perfectly tanned, they are to be removed, and slowly dried in the shade.

It has been proposed to use the residuum of the tanning lixivium, or the exhausted ooze (which contains a portion of gallic acid, this forming a constituent part of astringent vegetables), for the purpose of taking off the hair; but this liquor seems to contain no substances capable of acting upon the epidermis, or of loosening the hair; and when skin is depilated by being exposed to it, the effect must really be owing to incipient putrefaction.

The length of time necessary to tan leather completely, according to the old process, is certainly a very great inconvenience; and there is no doubt but that it may be much shortened by following the new method. It has been found, however, that the leather so tanned has not been so durable as that which has been formed by a slower process.

The public is much indebted to Sir Humphrey Davy, professor of chemistry in the Royal Institution, for the attention which he has paid to this subject. From his excellent paper "On the Constituent Parts of Astringent Vegetables," in the Philosophical Transactions, we present the reader with the following extract.

"In considering the relation of the different facts that have been detailed, to the processes of tanning and of leather-making, it will appear sufficiently evident, that when skin is tanned in astringent infusions that contain, as well as tanning, extractive matters, portions of these matters enter, with the tanning, into chemical combination with the skin. In no case is there any reason to believe that gallic acid is absorbed in this process; and M. Seguin's ingenious theory, of the agency of this substance, in producing the de-oxygenation of skin, seems supported by no proofs. Even in the formation of glue from skin, there is no evidence which ought to induce us to suppose that it loses a portion of oxygen; and the effect appears to be owing merely to the separation of the gelatine, from the small quantity of albumen with which it was combined in the organized form, by the solvent powers of water.

"The different qualities of leather made with the same kind of skin, seem to depend very much upon the different quantities of extractive matter it contains, The leather obtained by means of infusions of galls is generally found harder, and more liable to crack, than the leather obtained from the infusion of barks; and in all cases it contains a much larger proportion of tanning, and a smaller proportion of extractive matter.

"When skin is very slowly tanned in weak solutions of the barks, or of catechu, it combines with a considerable proportion of extractive matter; and in these cases, though the increase of weight of the skin is comparatively small, yet it is rendered perfectly insoluble in water, and is found soft, and at the same time strong. The saturated astringent infusions of barks contain much less extractive matter, in proportion to their tanning, than the weak infusions; and when skin is quickly tanned in them, common experience shews that it produces leather less durable than the leather slowly formed.

"Besides, in the case of quick tanning by means of infusions of barks, a quantity of vegetable extractive matter is lost to the manufacturer, which might have been made to enter into the composition of his leather. These observations shew that there is some foundation for the vulgar opinion of workmen, concerning what is technically called the

feeding of leather in the slow method of tanning; and though the processes of the art may, in some cases, be protracted for an unnecessary length of time, yet in general they appear to have arrived, in consequence of repeated practical experiments, at a degree of perfection which cannot be very far extended by means of any elucidations of theory that have as yet been known."

As a vast quantity of bark may easily be obtained in countries that are covered with natural forests, such as many parts of America, New Holland, &c. it has been suggested, as a method of lessening the expense of freight in bringing it over, to make an extract from the bark, which might be very easily transported, and which would serve the purpose of the tanner as well as the bark itself.

It was first suspected by Sir Joseph Banks, and afterwards confirmed by the experiments of Professor Davy, that a substance called *catechu* or *terra Japonica*, brought from the East Indies, contained a vast quantity of tannin; so much so, that it far excels every other known substance in this respect. One pound of catechu contains as much tannin as eight or ten pounds of common oak bark, and would consequently tan proportionately as much more leather. It is an extract made from the wood of a species of mimosa, by decoction and subsequent evaporation.

Oak bark being a very expensive article in the process of tanning, various substances have been proposed as substitutes for it. All the parts of vegetables which are of an astringent nature, contain tannin (which may be known by their giving precipitates with gelatine, insoluble in water), and will answer this purpose. The leaves, branches, fruit, flowers, of a vast number of plants; every part of the oak, as the leaves and acorns, oak saw-dust, and the bark of almost all trees, contain more or less tannin.

Mr. Biggins has made a great many experiments upon the quantity of tanning principle in various barks from which he has constructed the following table:

	Tanning principle (in grains), from half a pint of infusion and an ounce of solution of glue.
Bark of elm	28
oak, cut in winter	30
horse chesnut	30
beech	31
willow (boughs)	31
elder	41
plum-tree	58
willow (trunk)	52
sycamore	53
birch	54
cherry-tree	59
sallow	59
mountain-ash	60
poplar	76
hazel	79
ash	82
Spanish chesnut	98

	Tanning principle (in grains), from half a pint of infusion and an ounce of solution of glue.
Bark of smooth oak	104
oak, cut in spring	108
Huntingdon or Leicestershire willow	109
sumach	158

Currying.—The art of currying consists in rendering tanned skins supple and of uniform density, and impregnating them with oil, so as to render them in a great degree impervious to water.

The stronger and thicker hides are usually employed for making the soles of boots and shoes, and these are rendered fit for their several purposes by the shoemakers after they are tanned; but such skins as are intended for the upper leathers and quarters of shoes, for the legs of boots, for coach and harness leather, saddles, and other things, must be subjected to the process of currying.

These skins after coming from the tanners, having many fleshy fibres on them, are well soaked in common water. They are then taken out, and stretched upon a very even wooden horse; where with a paring knife all the superfluous flesh is scraped off, and they are again put in to soak. After the soaking is completed, the currier takes them again out of the water, and having stretched them out, presses them with his feet, or a flat stone fixed in a handle, to make them more supple, and to press out all the filth that the leather may have acquired in tanning, and also the water it has absorbed in soaking.

The skins are next to be oiled, to render them pliant and impervious to wet. After they are half dried, they are laid upon tables, and first the grain side of the leather is rubbed over with a mixture of fish-oil and tallow; then the flesh side is impregnated with a large proportion of oil. After having been hung up a sufficient time to dry, they are taken down and rubbed, pressed, and folded in various directions, and then spread out, when they are rolled with considerable pressure upon both sides with a fluted board, fastened to the operator's hand by a strap; by this means, and by repeating the rolling, a grain is given to the leather.

After the skins are curried, it may be required to colour them: the colours usually given to them are black, red, green, yellow, &c.

If the skins are to be blacked, the process varies according to the side of the skin to be coloured. Leather that is to be blacked on the flesh side, which is the case with most of the finer leathers intended for shoes and boots, is coloured with a mixture of lamp black, oil, and tallow, rubbed into the leather. And what is to be coloured on the grain side is done over with chamber-ley, and then with a solution of sulphate of iron (green copperas), which turns it black.

CHAP. XI.

JAPANNING.

Japanning is properly the art of varnishing and painting ornaments on wood, in the same manner as is done by the natives of Japan in the East Indies.

The substances which admit of being japanned are almost every kind that are dry and rigid, or not too flexible, as wood, metals, leather, and paper prepared.

Wood and metals do not require any other preparation, but to have their surfaces perfectly even and clean; but leather should be securely strained, either on frames or on boards; as its bending, or forming folds, would otherwise crack and force off the coats of varnish. Paper should be treated in the same manner, and have a previous strong coat of some kind of size; but it is rarely made the subject of japanning till it is converted into *papier machie*, or wrought by other means into such form, that its original state, particularly with respect to flexibility, is changed.

One principal variation from the method formerly used in japanning is, the omitting any priming or undercoat on the work to be japanned. In the older practice, such a priming was always used; the use of which was to save in the quantity of varnish, by filling up the inequalities in the surface of the substance to be varnished. But there is a great inconvenience arising from the use of it, that the japanned coats are constantly liable to be cracked, and peeled off, by any violence, and will not endure near so long as the articles which are japanned without any such priming.

The French still retain the use of this undercoat; and their japanned goods are upon that account less durable than those manufactured at Birmingham, where it is not used.

Of the Nature of Japanned Grounds.—When a priming is used, the work should first be prepared by being well smoothed with fish-skin or glass-paper, and being made thoroughly clean, should be brushed over once or twice with hot size, diluted with two-thirds water, if it is of the common strength. The priming should then be laid on as even as possible, and should be formed of a size of a consistency between the common kind and glue, mixed with as much whiting as well give it a sufficient body of colour to hide the surface of whatever it is laid upon, but not more. This must be repeated till the inequalities are completely filled up, and then the work must be cleaned off with Dutch rushes, and polished with a wet rag.

When wood or leather is to be japanned, and no priming is used, the best preparation is to lay two or three coats of coarse varnish, composed in the following manner:

Take of rectified spirits of wine one pint, and of coarse seed-lac and resin each two ounces; dissolve the seed-lac and resin in the spirit, and then strain off the varnish.

This varnish, as well as all others formed of spirits of wine, must be laid on in a warm place; and, if it can be conveniently managed, the piece of work to be varnished should be made warm likewise; and,

for the same reason all dampness should be avoided; for either cold or moisture chills this kind of varnish, and prevents its taking proper hold of the substance on which it is laid.

When the work is so prepared, or by the priming with the composition of size and whiting above described, the proper japan ground must be laid on, which is much the best formed of shell-lac varnish, and the colour desired, except white, which requires a peculiar treatment; and if brightness be wanted, then also other means must be pursued.

The colours used with the shell-lac varnish may be any pigments whatever, which give the tint of the ground desired.

As metals never require to be undercoated with whiting, they may be treated in the same manner as wood or leather.

White Japan Grounds.—The forming a ground perfectly white, and of the first degree of hardness, remains hitherto a desideratum in the art of japanning, as there are no substances which form a very hard varnish, but which have too much colour not to injure the whiteness, when laid on with a due thickness over the work.

The nearest approach, however, to a perfect white varnish, already known, is made by the following composition:

Take flake-white, or white lead, washed over and ground up with one-sixth of its weight of starch, and then dried; and temper it properly for spreading with mastic varnish.

Lay these on the ground to be japanned, prepared either with or without the under coat of whiting, in the manner as above ordered; and then varnish it over with five or six coats of the following varnish:

Provide any quantity of the best seed-lac, and pick out of it all the clearest and whitest grains, reserving the more coloured and fouler parts for the coarse varnishes, such as that used for priming or preparing wood or leather. Take of this picked lac two ounces, and of gum-animi three ounces; and dissolve them, being previously reduced to a gross powder, in about a quart of spirits of wine, and strain off the clear varnish.

The seed-lac will give a slight tinge to this composition; but it cannot be omitted where the varnish is wanted to be hard; though, when a softer will answer the end, the proportion may be diminished, and a little crude turpentine added to the gum-animi to take off the brittleness.

A very good varnish, entirely free from all brittleness, may be formed by dissolving as much gum-animi as the oil will take, in old nut or poppy-oil; which must be made to boil gently when the gum is put into it. The ground of white colour itself may be laid on in this varnish, and then a coat or two of it may be put over the ground; but it must be well diluted with oil of turpentine when it is used. This, though free from brittleness, is nevertheless liable to suffer by being indented or bruised by any slight strokes; and it will not well bear any polish, but may be brought to a very smooth surface without it if it be judiciously managed in the laying it on. It is likewise somewhat tedious in drying, and will require some time where several coats are laid on, as the last ought not to contain much oil of turpentine.

Blue Japan Grounds.—But japan grounds may be formed of bright Prussian-blue or of verditer, glazed over by Prussian-blue or smalt. The colour may be best mixed with shell-lac varnish, and brought to a

polishing state by five or six coats of varnish of seed-lac; but the varnish, nevertheles, will somewhat injure the colour, by giving to a true blue a cast of green, and fouling, in some degree, a warm blue by the yellow it contains: where, therefore, a bright blue is required, and a less degree of hardness can be dispensed with, the method before directed in the case of white grounds must be pursued.

Red Japan Grounds.—For a scarlet japan ground, vermilion may be used: but the vermilion has a glaring effect, that renders it much less beautiful than the crimson produced by glazing it over with carmine or fine lake, or even with rose pink, which has a very good effect used for this purpose. For a very bright crimson, nevertheless, instead of glazing with carmine, the Indian lake should be used, dissolved in the spirit of which the varnish is compounded, which it readily admits of when good; and in this case, instead of glazing with the shell-lac varnish, the upper or polishing coats need only be used, as they will equally receive and convey the tinge of the Indian lake, which may be actually dissolved by spirits of wine; and this will be found a much cheaper method than the using carmine. If, however, the highest degree of brightness is required, the white varnish must be used.

Yellow Japan Grounds.—For bright yellow grounds, King's yellow, or turpeth mineral, should be employed, either alone or mixed with fine Dutch pink, and the effect may be still more heightened by dissolving powdered turmeric-root in the spirits of wine, of which the upper or polishing coat is made, which spirits of wine must be strained from off the dregs before the seed-lac be added to it, to form the varnish.

The seed-lac varnish is not equally injurious here, and with greens, as is the case of other colours; because, being only tinged with a reddish yellow, it is little more than an addition to the force of the colours.

Yellow grounds may be likewise formed of Dutch pink only, which, when good, will not be wanting in brightness, though extremely cheap.

Green Japan Grounds.—Green grounds may be produced by mixing King's yellow and bright Prussian-blue, or rather turpeth mineral and Prussian-blue. And a cheap but fouler kind of verdigris, with a little of the above mentioned yellows or Dutch pink. But where a very bright green is wanted, the crystals of verdigris, called distilled verdigris, should be employed; and to heighten the effect, they should be laid on a ground of leaf-gold, which renders the colour extremely brilliant and pleasing.

Orange Japan Grounds.—Orange-coloured japan grounds may be formed by mixing vermilion. or red lead, with King's yellow or Dutch pink, or the orange lake, which will make a brighter orange ground than can be produced by any mixture.

Purple Japan Grounds.—Purple Japan grounds may be produced by the mixture of lake and Prussian-blue; of a darker kind, by vermilion and Prussian-blue. They may be treated as the rest with respect to the varnish.

Black Japan Grounds without Heat.—Black grounds may be formed by either ivory black or lamp black; but the former is preferable where it is perfectly good. These may always be laid on with shell-lac varnish; and have their upper or polishing coats of common seed-lac varnish, as the tinge or foulness of the varnish can here be no injury.

Common Black Japan Grounds on Iron or Copper, produced by Means of Heat.—For forming the black japan grounds by means of heat, the piece of work to be japanned must be painted over with drying oil, and a little lamp black; and when it is of a moderate dryness, must be exposed to such a degree of heat as will change the oil to black, without burning so as to destroy or weaken its tenacity. The stove should not be too hot when the work is put into it, nor the heat increased too fast, either of which errors would make it blister; but the slower the heat is augmented, and the longer it is continued, provided it be restrained within the due degree, the harder will be the coat of japan. This kind of varnish requires no polish, having received, when properly managed, a sufficient one from the heat.

The fine Tortoise-shell Japan Ground, produced by Means of Heat.—The best kind of tortoise-shell ground produced by heat is not less valuable for its great hardness, and enduring to be made hotter than boiling water without damage, than for its beautiful appearance. It is to be made by means of a varnish prepared in the following manner:

Take of good linseed-oil one gallon, and of umber half a pound; boil them together till the oil become very brown and thick; strain it through a coarse cloth, and set it again to boil; in which state it must be continued till it acquire a pitchy consistence, when it will be fit for use.

Having thus prepared the varnish, clean well the iron or copper plate, or other pieces which are to be japanned, and then lay vermilion tempered with shell-lac varnish, or with drying oil diluted with oil of turpentine, very thinly, on the places intended to imitate the more transparent parts of the tortoise-shell. When the vermilion is dry, brush over the whole with the black varnish, tempered to a true consistence with oil of turpentine; and when it is set and firm, put the work into a stove, where it may undergo a very strong heat, and must be continued a considerable time: if even three weeks or a month it will be the better.

This was given amongst other receipts by Kunckel; but appears to have been neglected till it was revived with great success in the Birmingham manufactures, where it was not only the ground of snuff-boxes, dressing-boxes, and other such lesser pieces; but of those beautiful tea-waiters which have been so justly esteemed and admired in several parts of Europe, where they have been sent. This ground may be decorated with painting and gilding, in the same manner as any other varnished surface, which had best be done after the ground has been duly hardened by the hot stove; but it would be best to give a second annealing with a more gentle heat, after it is finished.

Method of Painting Japan Work.—Japan work ought properly to be painted with colours in varnish; though, for the greater dispatch, and in some very nice work in small, for the freer use of the pencil, the colours are sometimes tempered in oil; which should previously have a fourth part of its weight of gum-animi dissolved in it; or in default of that, gum-sandarac or gum-mastic. When the oil is thus used, it should be well diluted with oil of turpentine, that the colours may lay more evenly and thin; by which means, fewer of the polishing or upper coats of varnish become necessary.

In some instances, water colours are laid on grounds of gold, in the manner of other paintings; and are best when so used in their

proper appearance, without any varnish over them; and they are also sometimes so managed as to have the effect of embossed work. The colours employed in this way for painting are best prepared by means of isinglass size, corrected by honey or sugar-candy. The body of which the embossed work is raised, need not, however, be tinged with the exterior colour, but may be best formed of very strong gum-water, thickened to a proper consistence by bole Armenian and whiting in equal parts; which being laid on the proper figure, and repaired when dry, may be then painted with the proper colours, tempered with the isinglass size, or, in the usual manner, with shell-lac varnish.

Manner of Varnishing Japan Work.—The finishing of japan-work lies in the laying on and polishing the outer coats of varnish which are necessary, as well in the pieces that have only one simple ground of colour, as with those that are painted. This is in general done best with common seed-lac varnish, except in the instances, and on those occasions, where we have already shewn other methods to be more expedient; and the same reasons which decide as to the fitness or impropriety of the varnishes, with respect to the colours of the ground, hold equally with regard to those of the painting. For where brightness is the most material point, and a tinge of yellow will injure it, seed-lac must give way to the whiter gums; but where hardness and a greater tenacity are most essential, it must be adhered to; and where both are so necessary, that it is proper one should give way to the other in a certain degree reciprocally, a mixed varnish must be adopted.

This mixed varnish, as we have already observed, should be made of the picked seed-lac. The common seed-lac varnish, which is the most useful preparation of the kind hitherto invented, may be thus made:

Take of seed-lac three ounces, and put it into water, to free it from the sticks and filth that are frequently intermixed with it; and which must be done by stirring it about, and then pouring off the water, and adding fresh quantities, in order to repeat the operation, till it be freed from all impurities, as is very effectually done by this means. Dry it then, and powder it grossly, and put it, with a pint of rectified spirits of wine, into a bottle, of which it will not fill above two thirds. Shake the mixture well together, and place the bottle in a gentle heat, till the seed-lac appears to be dissolved; the shaking being in the meantime repeated as often as may be convenient: and then pour off all that can be obtained clear by this method, and strain the remainder through a coarse cloth. The varnish thus prepared must be kept for use in a bottle well stopped.

When the spirit of wine is very strong, it will dissolve a greater proportion of the seed-lac; but this quantity will staturate the common, which is seldom of a strength sufficient to make varnishes in perfection. As the chilling, which is the most inconvenient accident attending varnishes of this kind, is prevented or produced more frequently according to the strength of the spirit; we shall, therefore, take this opportunity of shewing a method by which weaker rectified spirits may with great ease at any time be freed from the phlegm, and render it of the first degree of strength.

Take a pint of the common rectified spirits of wine, and put it into

a bottle, of which it will not fill above three parts; add to it half an ounce of pearl-ashes, salt of tartar, or any other alkaline salt, heated red hot, and powdered as well as it can be without much loss of its heat. Shake the mixture frequently for the space of half an hour; before which time, a great part of the phlegm will be separated from the spirits, and will appear, together with the undissolved part of the salts, in the bottom of the bottle. Let the spirit be poured off, or freed from the phlegm and the salt, by means of a tritorium, or separating funnel; and let half an ounce of the pearl-ashes, heated and powdered as before, be added to it, and the same treatment repeated. This may be done a third time, if the quantity of phlegm separated by the addition of the pearl-ashes appear considerable. An ounce of alum reduced to powder, and made hot, but not burnt, must then be put into the spirit, and suffered to remain some hours, the bottle being frequently shaken; after which, the spirit being poured off from it, will be fit for use.

The addition of the alum is necessary to neutralize the remains of the alkaline salt, which would otherwise greatly deprave the spirit, with respect to varnishes and lacquer where vegetable colours are concerned, and must consequently render another distillation necessary.

The manner of using the seed-lac or white varnish is the same, except with regard to the substance used in polishing; which, where a pure white of a great clearness of other colours is in question, should be itself white; whereas the browner sorts of polishing-dust, as being cheaper, and doing their business with greater dispatch, may be used in other cases. The pieces of work to be varnished should be placed near a fire, or in a room where there is a stove, and made perfectly dry; and then the varnish may be rubbed over them by the proper brushes made for that purpose, beginning in the middle, and passing the brush to one end, and then with another stroke from the middle, passing it to the other. But no part should be crossed, or twice passed over, in forming one coat, where it can be possibly avoided. When one coat is dry, another must be laid over it; and this must be contined at least five or six times or more, if, on trial, there be not sufficient thickness of varnish to bear the polish without laying bare the painting or ground-colour underneath.

When a sufficient number of coats is thus laid on, the work is fit to be polished; which must be done, in common cases, by rubbing it with a rag dipped in tripoli or rotten-stone finely powdered; but towards the end of the rubbing, a little oil of any kind should be used along with the powder; and when the work appears sufficiently bright and glossy, it should be well rubbed with the oil alone, to clean it from the powder, and give it a still brighter lustre.

In case of white grounds, instead of tripoli or rotten-stone, fine putty or whiting must be used; both of which should be washed over to prevent the danger of damaging the work, from any sand or gritty matter that may happen to be mixed with them.

It is a great improvement in all kinds of japan-work, to harden the varnish by means of heat; which in every degree that it can be applied, short of what would burn or calcine the matter, tends to give it a more firm and strong texture.

Where metal forms the body, a very hot stove may be used; and the pieces of work may be continued in it a considerable time, especially

if the heat be gradually increased; but where wood is in question, heat must be sparingly used, as it would otherwise warp or shrink the body, so as to injure the general figure.

CHAP. XII.

LACQUERING.

Lacquering is the laying either coloured or transparent varnishes on metals, in order to produce the appearance of a different colour in the metal, or to preserve it from rust, or the injuries of the weather.

Lacquering is used where brass is to be made to have the appearance of being gilt; where tin is wanted to have the resemblance of yellow metals; and where brass locks or nails, or other such matters, are to be defended from the corrosion of the air or moisture.

The principal substance used for the composition of lacquers, is seed-lac; but for coarser purposes resin or turpentine is added, in order to make the lacquer cheaper,

A Lacquer for Brass, to imitate Gilding.—Take of turmeric one ounce, and of saffron and Spanish annatto, each two drachms. Put them into a proper bottle with a pint of highly rectified spirits of wine, and place them in a moderate heat, often shaking them for several days. A very strong yellow tincture will then be obtained, which must be strained off from the dregs through a coarse linen cloth; and then, being put back into the bottle, three ounces of good seed-lac, powdered grossly, must be added, and the mixture placed again in a moderate heat, and shaken till the seed-lac be dissolved, or at least such a part of it as may. The lacquer must then be strained, and must be put into a bottle well corked.

Where it is desired to have the lacquer warmer or redder than this composition, the proportion of the annatto must be increased; and where it is wanted cooler, or nearer to a true yellow, it must be diminished.

The above, properly managed, is an extremely good lacquer, and of moderate price; but the following, which is cheaper, and may be made where the Spanish annatto cannot be procured good, is not greatly inferior to it.

Take of turmeric root, ground, one ounce, of the best dragon's blood half a drachm; put them to a pint of spirits of wine, and proceed as above. By diminishing the proportion of dragon's blood, the varnish may be rendered of a redder or truer yellow cast.

Saffron is sometimes used to form the body of colour in this kind of lacquer, instead of the turmeric; but though it makes a warmer yellow, yet the dearness of it, and the advantage which turmeric has in forming a much stronger tinge in spirits of wine, gives it the preference. Though being a true yellow, and consequently not sufficiently warm to overcome the greenish cast of brass, it requires the addition of some orange-coloured tinge to make it a perfect lacquer.

Aloes and gamboge are also sometimes used in lacquers for brass;

but the aloes are not necessary where turmeric or saffron is used; and the gamboge, though a very strong milky juice in water, affords but a very weak tinge in spirits of wine.

A Lacquer for Tin, to imitate a Yellow Metal.—Take of turmeric root one ounce, of dragon's blood two drachms, and of spirits of wine one pint; add a sufficient quantity of seed-lac.

A Lacquer for Locks, &c.—Seed-lac varnish alone, or with a little dragon's blood: or a compound varnish of equal parts of seed-lac and resin, with or without the dragon's blood.

A Gold-coloured Lacquer for gilding Leather.—What is called *gilt leather,* and used for skreens, borders for rooms, &c. is only leather covered with *silver* leaf, and lacquered with the following composition:

Take of fine white resin four pounds and a half, of common resin the same quantity, of gum sandarac two pounds and a half, and of aloes two pounds; mix them together, after having bruised those which are in great pieces, and put them into an earthen pot, over a good fire made of charcoal, or over any fire where there is no flame. Melt all the ingredients in this manner, stirring them well with a spatula, that they may be thoroughly mixed together, and be prevented also from sticking to the bottom of the pot. When they are perfectly melted, and mixed, add gradually to them seven pints of linseed oil, and stir the whole well together with the spatula. Make the whole boil, stirring it all the time to prevent a kind of sediment that will form, from sticking to the bottom of the vessel. When the varnish is almost sufficiently boiled, add gradually half an ounce of litharge, or half an ounce of red-lead, and when they are dissolved, pass the varnish through a linen cloth, or flannel bag.

The time of boiling this varnish should be about seven or eight hours. This, however, varies according to circumstances. The way of knowing when it is sufficiently boiled, is by taking a little on some instrument, and if it draws out and is ropy, and sticks to the fingers, drying on them it is done; but if not, it must be boiled till it acquires these qualities.

CHAP. XIII.

GILDING.

GILDING is the application of gold to the surfaces of bodies: it is of two principal kinds, according to the method of applying the gold.

Wood, leather, paper, and similar substances, are gilt by fastening on leaves of gold by means of some cement. But metals are gilt by a chemical application of the gold to the surface. This last is called *water gilding.*

The gilding of wood, and similar substances, is of three kinds; *oil gilding, burnished gilding,* and *japanners' gilding,* which we shall severally describe, after noticing the materials and tools necessary for going to work.

Of Gold-Leaf.—There are three kinds of gold-leaf in common use.

Pure gold-leaf, which is made by hammering gold between the leaves of a book made of skins, till they are sufficiently thin.

Pale leaf-gold, which has a greenish colour, and is made of gold alloyed with silver.

Dutch gold, which is brought from Holland, and is in fact only copper-leaf coloured by the fumes of zinc. It is much cheaper than true leaf-gold, and is very useful where large quantities of gilding are wanted, which can be defended from the weather, and where great nicety is not required; but it changes its colour entirely when exposed to moisture; and, indeed, in all cases, its beauty is soon impaired, unless well secured by varnish. It is therefore only a cheap substitute for true gold-leaf, which may be useful where durability is not an object.

Of the Instruments necessary for Gilding.—The first instrument is the *cushion,* for receiving the leaves of gold from the books in which they are bought. It is made by covering a board of about eight inches square, with a double thickness of flannel, and over that, a piece of buff leather, and fastening it tight round the edges.

The *knife* for cutting the leaves into the requisite sizes, should be made like a pallet knife, and should not have its edge too sharp.

The *tip* is a tool made by fastening the long hairs of a squirrel's tail between two cards, and is used for taking up the gold-leaf after it is cut, and applying it to the article to be gilded.

A *fitch pencil* is used for the same purpose as the last, in taking up very small bits of gold-leaf. A *ball of cotton* is necessary for pressing down the leaf, after it is laid on. A large *camel's-hair brush* is used for dusting the work, and clearing away the superfluous gold.

Oil Gilding.—First prime your work with boiled linseed-oil and white-lead; and when that is dry, do it over with a thin coat of gold size, made of stone ochre ground in fat oil. When that is so dry as to feel clammy to the fingers, or to be, as the gilders call it, *tacky,* it is fit for gilding. Having spread your leaves upon the cushion, cut them into slips of the proper width for covering your work. Then breathe upon your tip, which, by moistening it, will cause it to take up the leaves from the cushion. Having applied them by the tip on the proper parts of your work, press them down by the ball of cotton. Observe to repair, by putting small pieces of gold on any parts which you have omitted to cover. When all your work is sufficiently covered, let it dry, and clean it off with the brush.

This sort of gilding is the easiest, least expensive, and stands the weather best, and may be cleaned with a little water at any time; but wants the lustre of burnish gilding.

Burnished Gilding.—This is the sort of gilding generally used for picture-frames, looking-glasses, &c.

The wood intended to be gilt in this manner, should first be well sized, and then done over with seven or eight coats of size and whiting, so as to cover it with a body of considerable thickness. Having got a sufficient quantity of whiting upon the work, it must be carefully cleaned off, taking care to free all the cavities, and hollows from the whiting that may have choked them up, and by proper moulds and tools, restoring the sharpness of the mouldings intended to be shewn.

It is then to receive a coat of size, which is made by boiling armenian bole with parchment size. This must also remain till it is suffi-

ciently dry for the gold. It must not be quite dry, therefore it would not be prudent to lay on more at a time, than can be gilt before it becomes too dry.

The work being thus prepared, place it a little declining from you, and having ready a cup of clean water, and some hair pencils, moisten a part of the work, and then apply the gold by the tip to the moistened part The gold will immediately adhere close to the work: proceed to wet the next part, and apply the gold as before, repeating this operation till the whole is completed; taking care not to let any drops of water come upon any part of the gold already laid on. Care should therefore be taken, that no part be missed in going over it at first, as it is not so easily mended as the oil gilding.

The work being thus gilt, it is suffered to remain about twenty-four hours; when the parts that are designed to be burnished are polished with a dog's tooth, or what is better, with an agate burnisher. The gilding must not be quite dry when it is burnished: there is a state proper for the purpose, which is only to be known by experience.

Japanners Gilding.—The gilding of japanned work consists in drawing with a hair pencil, in gold size, the intended ornaments, and afterwards applying gold leaf or gold powder.

The gold size may be prepared in the following manner: Take of linseed-oil, and of gum animi, four ounces. Set the oil to boil in a proper vessel, and then add the gum animi gradually in powder, stirring each quantity about in the oil, till it appear to be dissolved, and then putting in another, till the whole be mixed with the oil. Let the mixture continue to boil, till, on taking a small quantity out, it appear of a thicker consistence than tar, and then strain the whole through a coarse cloth, and keep it for use; but it must, when applied, be mixed with vermilion and oil of turpentine.

Having laid on the gold size, and suffered it to dry, the gold leaf is applied in the usual way, or if it is not wanted to shine so much, gold powder is applied, which is made by grinding gold leaf upon a stone with honey, and afterwards washing the honey away with water. If the gilding is to be varnished over, Dutch gold may be used, or aurum musivum may be used instead of real gold powder.

To write on Paper with Letters of Gold.—Put some gum arabic into common writing ink, and write with it in the usual way. When the writing is dry, breathe on it; the warmth and moisture softens the gum, and will cause it to fasten on the gold leaf, which may be laid on in the usual way, and the superfluous part brushed off. Or instead of this, any japanners' size may be used.

To lay Gold upon White Earthen-ware, or Glass.—Procure some japanners gold size, and with it draw your design upon the vessel to be gilt, moistening the gold size, as you find necessary, with oil of turpentine. Set your work in a clean place to dry, for about an hour, and then place it so near the fire that you could but just bear the heat of it with your hand for a few seconds. Let it remain there till it feels quite tacky or clammy, then, having procured a cushion, and some leaf gold, cut it into slips of the proper size, and lay it on with a little cotton wool. When the gold is all on, put the ware into an oven to be baked for two or three hours.

Glasses, &c. may also be gilt, by drawing the figures with shell gold

mixed with gum arabic, and a little borax. Then apply sufficient heat to it, and lastly, burnish it.

Gilding on Glass or Porcelain, by Burning-in.—Dissolve gold in aqua regia, and evaporate the acid by heat; you will obtain a gold powder; or precipitate the gold from the solution by pieces of copper. Lay this gold on with a strong solution of borax and gum water, and it will be ready for burning-in.

Gilding Metals.—One method of applying gold upon metals, is by first cleaning the metal to be gilt; then gold leaf is laid on it, which, by means of rubbing with a polished blood stone, and a certain degree of heat, are made to adhere perfectly well. In this manner silver leaf is fixed and burnished upon brass, in the making of what is called *French plate;* and sometimes also gold leaf is burnished upon copper and iron.

Gilding by Amalgamation is by previously forming the gold into a paste, or amalgam, with mercury.

In order to obtain an amalgam of gold and mercury, the gold is first to be reduced into thin plates or grains, which are heated red-hot, and thrown into mercury previously heated, till it begins to smoke. Upon stirring the mercury with an iron rod, the gold totally disappears. The proportion of mercury to gold, is generally as six or eight to one.

The method of gilding by amalgamation, is chiefly used for gilding copper, or an alloy of copper, with a small portion of zinc, which more readily receives the amalgam, and is also preferable, on account of its colour, which more resembles that of gold than the colour of copper.

When the metal to be gilt is wrought or chased, it ought to be previously covered with quick-silver before the amalgam is applied, that this may be easier spread; but when the surface of the metal is plane, the amalgam may be directly applied to it.

The metal required to be gilt is first rubbed over with a little aquafortis, by which the surface is cleaned from any rust or tarnish that might prevent the union of the two metals. The amalgam being then equally spread over the surface by means of a brush, the mercury is evaporated by a heat just sufficient for that purpose; for if it be too great, part of the gold may also be expelled, and part of it will run together, and leave some of the surface of the metal bare. While the mercury is evaporating, the piece is to be from time to time taken from the fire, that it may be examined; that the amalgam may be spread more equally by means of a brush; that any defective parts of it may be again covered, and that the heat may not be too suddenly applied to it. When the mercury is evaporated, which is known by the surface becoming entirely of a dull yellow colour, the metal must then undergo other operations, by which the fine gold colour is given to it.

First, the gilded piece of metal is rubbed with a *scratch-brush* (which is a brush composed of brass-wire), till its surface is made smooth; then it is covered over with a composition, called *gilding wax,* and is again exposed to the fire till the wax be burnt off. This wax is composed of bees-wax, sometimes mixed with some of the following substances: red ochre, verdigris, copper scales, alum, vitriol, borax; but, according to Dr. Lewis, the saline substances are sufficient, without any wax.

By this operation the colour of the gilding is heightened; and this effect seems to be produced by a perfect dissipation of some mercury remaining after the former operation.

The gilt surface is then covered over with a saline composition, consisting of nitre, alum, or other vitriolic salt, ground together, and mixed up into a paste with water or urine. The piece of metal thus covered is exposed to a certain degree of heat, and then quenched in water. By this method its colour is further improved, and brought nearer to that of gold. This effect seems to be produced by the acid of nitre (which is disengaged by the sulphuric acid of the alum, during the exposure to heat) acting upon any particles of copper which may happen to lie upon the gilded surface.

Lastly, some artists think that they give an additional lustre to their gilt work, by dipping it in a liquor prepared by boiling some yellow materials, as sulphur, or piment or turmeric. The only advantage of this operation is, that part of the yellow matter remains in some of the hollows of the carved work, in which the gilding is apt to be more imperfect, and to which it gives a rich and solid appearance.

It may here be noticed, that the use of the aquafortis or nitrous acid, mentioned in the beginning of the process, is not, as is generally supposed, confined merely to cleansing the surface of the metal to be gilt from rust or tarnish; but it also greatly facilitates the application of the amalgam to the surface of that metal, probably in the following manner: It first dissolves part of the mercury of the amalgam; and when this solution is applied to the copper, this latter metal having a stronger disposition to unite with the nitrous acid than the mercury has, precipitates the mercury upon its surface, in the same manner as a polished piece of iron precipitates upon its surface copper from a solution of blue vitriol. When the metal to be gilt is thus covered over with a thin coat of precipitated mercury, it readily receives the amalgam.

On the subject of gilding by amalgamation, Dr. Lewis has the following remarks: "There are two principal inconveniences in this business; one, that the workmen are exposed to the fumes of the mercury, and generally, sooner or later, have their health greatly impaired by them: the other, the loss of the mercury; for though part of it is said to be detained in the cavities made in the chimnies for that purpose, yet the greatest part of it is lost. From some trials I have made, it appeared that both these inconveniences, particularly the first and most considerable one, might be in a good measure avoided, by means of a furnace of a due construction."

If the communication of a furnace with its chimney, instead of being over the fire, is made under the grate, the ash-pit door, or other apertures beneath the grate, closed, and the mouth of the furnace left open, the current of air, which otherwise would have entered beneath, enters now at the top, and passing down through the grate to the chimney, carries with it completely both the vapour of the fuel, and the fumes of such matters as are placed upon it. The back part of the furnace should be raised a little higher above the fire than the fore part, and an iron plate laid over it, that the air may enter only at the front where the workman stands, who will be thus effectually secured from the fumes, and from being incommoded by the heat, and at the same time have full liberty of introducing, inspecting, and removing the work.

If such a furnace is made of strong forged (not milled) iron plate, it will be sufficiently durable. The upper end of the chimney may reach above a foot and a half higher than the level of the fire; over this is to be placed a larger tube, leaving an interval of an inch or more, all round between it and the chimney, and reaching to the height of ten or twelve feet; the higher the better. The external air passing up between the chimney and the outer pipe, prevents the latter from being much heated, so that the mercurial fumes will condense against its sides into running quicksilver, which falling down to the bottom, is there catched in a hollow rim, formed by turning inwards a portion of the lower part, and conveyed by a pipe at one side into a proper receiver.

Gilding Iron or Steel.—In gilding iron or steel by means of an amalgam, as the metal has no affinity for the mercury, an agent must be employed to dispose the surface to receive the gilding. For this purpose, a solution of mercury in nitrous acid (aquafortis), or what the workmen call quicksilver water, is applied to the parts intended to be gilded; the acid, by a stronger affinity, seizes on a portion of the iron, and deposits in the place of it a thin coating of mercury, which will not refuse a union afterwards with the gold amalgam that may be applied; but by this process, the surface of the metal is injured by the nitrous acid, and the union of the mercury is very slight, so that a bright and durable gilding cannot be obtained.

Another method.—Sometimes a solution of *blue vitriol* is applied with a camel's-hair pencil to the parts of the steel intended to be gilt. By a chemical action, exactly similar to what we have described as taking place when a solution of nitrate of mercury is employed, a thin coating of copper is precipitated on the metal. Copper having an affinity for mercury, a kind of union may by this means be effected between the amalgam and the iron or steel, as the case may be. In whichever of these ways the amalgam be brought into union with the steel, the surface is injured by the action of the acid employed, and still a heat sufficient to volatilize the mercury must be afterwards used.

Gilding of Iron by Heat.—When the surface is polished bright, it must be heated till it becomes blue. Gold leaf is then applied to its surface, and burnished down. It is then heated again, and another layer of gold burnished on it. In this manner three or four coats are given, according to the strength of the gilding intended. This is a more laborious process than the two last, but it is not attended with so much risk.

An improved Process for Gilding Iron or Steel.—This process, which is less known among artists than it deserves to be, may prove useful to those who have occasion to gild iron or steel. The first part of the process consists in pouring over a solution of gold in nitro-muriatic acid (aqua regia) about twice as much ether, which must be done with caution, and in a large vessel. These liquids must then be shaken together; as soon as the mixture is at rest, the ether will be seen to separate itself from the nitro-muriatic acid, and to float on the surface. The nitro-muriatic acid becomes more transparent, and the ether darker than they were before; the reason of which is, that the ether has taken the gold from the acid. The whole mixture is then to be poured into a glass funnel, the lower aperture of which is small; but this aperture must not be opened till the fluids have completely separated themselves from each

other. It is then to be opened; by which means the liquid which has taken the lowest place by its greater gravity, viz. the nitro-muriatic acid, will run off; after which, the aperture is to be shut, and the funnel will then be found to contain nothing but ether mixed with the gold; which is to be put into well-closed bottles, and preserved for use. In order to gild iron or steel, the metal must first be well polished with the finest emery, or rather with the finest crocus martis or colcothar of vitriol, and common brandy. The auriferous ether is then to be applied with a small brush; the ether soon evaporates, and the gold remains on the surface of the metal. The metal may then be put into the fire, and afterwards polished. By means of this auriferous ether, all kinds of figures may be delineated on iron, by employing a pen, or fine brush. It is in this manner, we believe, that the Sohlinger sabre blades are gilded.

Instead of ether, the essential oils may be used, such as oil of turpentine, or oil of lavender, which will also take gold from its solution.

Cold Gilding of Silver.—Dissolve gold in the nitro-muriatic acid, and dip some linen rags in the solution; then burn them, and carefully preserve the ashes, which will be very black, and heavier than common. When any thing is to be gilded, it must be previously well burnished; a piece of cork is then to be dipped, first into a solution of salt in water, and afterwards into the black powder; and the piece, after being rubbed with it, must be burnished. This powder is frequently used for gilding delicate articles of silver.

Gilding of Brass or Copper.—Fine instruments of brass, in order that their surface may be kept longer clean, may be gilded in the following manner:

Provide a saturated solution of gold, and having evaporated it to the consistence of oil, suffer it to shoot into crystals. These crystals must then be dissolved in pure water, and the articles to be gilded being immersed in it, are then to be washed in pure water, and afterwards burnished. This process may be repeated several times, till the articles have been well gilt. A solution of gold crystals is preferred to a mere solution of gold, because, in the latter, there is always a portion of free acid, which will not fail to exercise more or less action on the surface of the brass or copper, and injure its polish.

Grecian Gilding.—Dissolve some mercury in muriatic acid (spirits of salt), which will give a muriat of mercury. Mix equal parts of this and sal ammoniac, and dissolve them in aquafortis. Put some gold into this, and it will dissolve.—When this is applied to silver, it becomes black; but, by heating, it assumes the appearance of gilding.

To make Shell-Gold.—Grind up gold leaf with honey, in a mortar; then wash away the honey with water, and mix the gold powder with gum water. This may be applied to any article with a camel's hair pencil, in the same way as any other colour.

Silvering.—Wood, paper, &c. are silvered in the same manner as gilding is performed, using only silver instead of gold leaf.

To silver Copper or Brass.—Cleanse the metal with aquafortis, by washing it lightly, and then throwing it into water; or by scouring it with salt and tartar with a wire brush. Dissolve some silver in aquafortis, and put pieces of copper into the solution; this will throw down the silver in a state of a metallic powder. Take fifteen or twenty grains of this

silver powder, and mix with it two drachms of tartar, the same quantity of common salt, and half a drachm of alum; rub the articles with this composition till they are perfectly white, then brush it off, and polish them with leather.

Another method.—Precipitate silver from its solution in aquafortis by copper, as before; to half an ounce of this silver, add common salt and sal ammoniac, of each two ounces, and one drachm of corrosive sublimate; rub them together, and make them into a paste with water. With this, copper utensils of every kind, that have been previously boiled with tartar and alum, are rubbed; after which they are made red hot and polished.

To Silver the Dial-plates of Clocks, Scales of Barometers, &c.—Take half an ounce of silver lace, add thereto an ounce of double refined aquafortis, put them into an earthen pot, and place them over a gentle fire till all is dissolved, which will happen in about five minutes; then take them off, and mix it in a pint of clear water, after which, pour it into another clean vessel, to free it from grit or sediment; then add a spoonful of common salt, and the acid, which has now a green tinge, will immediately let go the silver particles, which form themselves into a white curd; pour off the acid, and mix the curd with two ounces of salt of tartar, half an ounce of whiting, and a large spoonful of salt, more or less, according as you find it for strength. Mix it well up together, and it is ready for use.

Having well cleared the brass from scratches, rub it over with a piece of old hat and rotten-stone, to clear it from all greasiness, and then rub it with salt and water with your hand: take a little of the beforementioned composition on your finger, and rub it over where the salt has touched, and it will adhere to the brass, and completely silver it. After which wash it well with water, to take off what aquafortis may remain in the composition; when dry, rub it with a clean rag, and give it one or two coats of varnish, prepared according to the directions given under the article *varnishes.*

This silvering is not durable, but may be improved by heating the article, and repeating the operation till the covering seems sufficiently thick.

Silver Plating.—The coat of silver applied to the surface of the copper by the means mentioned above, is very thin, and is not durable. A more substantial method of doing it, is as follows: form small pieces of silver and copper, and tie them together with wire, putting a little borax between. The proportion of silver may be to that of the copper as 1 to 12. Put them into a white heat, when the silver will be firmly fixed to the copper. The whole is now made to pass between rollers, till it is of the required thickness for manufacturing various articles.

To make French Plate.—Heat the copper articles intended to be plated, and burnish silver leaf on it with a burnisher.

To make Shell Silver.—Grind up leaf silver with gum-water or honey; when you have ground it, wash away the gum or honey, and use the powder that remains with gum-water or glair of eggs. This is laid on with a hair pencil.

To silver Looking Glasses.—In order to go completely forward, you must be prepared with the following articles:

First, a square marble slab or smooth stone, well polished, and

ground exceedingly true, the larger the better, with a frame round it, or a groove cut in its edges, to keep the superfluous mercury from running off. Secondly, Lead weights covered with cloth, to keep them from scratching the glass, from one pound weight to twelve pounds each, according to the size of the glass which is laid down. Thirdly, Rolls of tinfoil. Fourthly, Mercury or quicksilver, with which you must be well provided; then proceed as follows:

Cut the tinfoil a little larger than the glass every way, and lay it flat upon the stone; and with a straight piece of hard wood, about three inches long, stroke it every way, that there be no creases or wrinkles in it, then drop a little mercury upon it, and with a piece of cotton, wool, or hare's-foot, spread it all over the foil, so that every part may be touched with the mercury. Then keeping the marble slab nearly level with the horizon, pour on the mercury all over the foil, cover it with a fine paper, and lay two weights very near its lowest end or side, to keep the glass steady while you draw the paper from between the silver foil and the glass, which must be laid upon the paper. As you draw the paper, you must take care that no air-bubbles be left, for they will always appear if left in at the first; you must likewise be sure to make the glass as clean as possible on the side intended to be silvered, and have the paper also quite clean, otherwise, when you have drawn the paper from under it, dull white streaks will appear, which are very disagreeable.

After the paper is drawn out, place as many weights upon the glass as you conveniently can, in order to press out the superfluous mercury, and make the foil adhere to the glass. When it has lain six or seven hours in this situation, raise the stone about two or three inches at its highest end, that as much of the mercury may run off as possible: let it remain two days before you venture to take it up; but before you take the weights off, gently brush the edges of the glass, that no mercury may adhere to them; then take it up, and turn it directly over, with its face side downward, but raise it by degrees that the mercury may not drip off too suddenly; for if, when taken up, it is immediately set perpendicular, air will get in between the foil and the glass at the top, as the mercury descends to the bottom; by which means, if you be not exceedingly careful, your labour will be lost.

Another method is to slide the glass over the foil, without the assistance of paper.

To silver Glass Globes.—Take half an ounce of clean lead, and melt it with an equal weight of pure tin; then immediately add half an ounce of bismuth, and carefully skim off the dross; remove the mixture from the fire, and before it grows cold, add five ounces of mercury, and stir the whole well together; then put the fluid amalgam into a clean glass, and it is fit for use.

When this amalgam is used for foiling or silvering, let it first be strained through a linen rag; then gently pour some ounces thereof into the globe intended to be foiled; the mixture should be poured into the globe, by means of a glass or paper funnel reaching almost to the bottom of the globe, to prevent its splashing to the sides; the globe should then be dexterously inclined every way, though very slowly, in order to fasten the silvering: when this is once done, let the globe rest some hours; repeat the operation, till at length the fluid mass is spread even, and fixed over the whole internal surface; as it may be

known to be, by viewing the globe against the light; the superfluous amalgam may then be poured out, and the outside of the globe cleared.

To silver the Convex Side of Meniscus Glasses for Mirrors.—Take an earthen plate, on which pour some prepared plaster of Paris, mixed with water, of a proper consistence; then immediately, before it grows too stiff, lay the meniscus with its convex side downward in the middle of the plate, and press it until it lies quite close to the plaster; in which situation let it remain until the plaster becomes quite dry; after which, work a groove with your finger round the outside of the meniscus, in order to let the superfluous mercury rest upon it; then cut the tinfoil to a proper size, and press it with the meniscus into the plaster mould, in order to make it lie close; after which cover it with the mercury, and, without a paper (as directed for silvering plain mirrors), slide it over the silvered foil; then place a weight on it, and let it stand two or three days, raising it by degrees, that the mercury may drip off gradually.

After this method common window glass, &c. may be silvered.

To lay Paper Prints on the Inside of Glass Globes.—First, Cut off all the white part of your impression, so that nothing appear but the print; then prepare some strong gum-arabic water or size, with which you must brush over the face side; after which put it into the globe, and with a long small stick, on which a camel's-hair pencil is fixed, stick it even on, and by this method you may put what number of prints you please into the globe; let them dry about twelve hours, then pour some prepared plaster of Paris, either white or tinged, whatsoever colour you please, and turn the globe easily about, so that every part be covered: pour out the superfluous plaster, and it is finished.

Tinning.—Tinning is the art of covering any metal with a thin coating of tin. Copper and iron are the metals most commonly tinned. The use of tinning these metals is to prevent them from being corroded by rust, as tin is not so easily acted upon by the air or water as iron and copper are.

What are commonly called tin-plates, or sheets, so much used for utensils of various kinds, are in fact iron plates coated with tin.

The principal circumstance in the art of tinning, is to have the surfaces of the metal to be tinned perfectly clean and free from rust, and also that the melted tin be perfectly metallic, and not covered with any ashes or calyx of tin.

Tinning of Iron.—When iron plates are to be tinned, they are first scoured, and then put into what is called a pickle, which is oil of vitriol diluted with water; this dissolves the rust or oxyde that was left after scouring, and renders the surface perfectly clean. They are then again washed and scoured. They are now dipped into a vessel full of melted tin, the surface of which is covered with fat or oil, to defend it from the action of the air. By this means, the iron coming into contact with the melted tin in a perfectly metallic state, it comes out completely coated.

When a small quantity of iron only is to be tinned, it is heated, and the tin rubbed on with a piece of cloth, or some tow, having first sprinkled the iron with some powdered resin, the use of which is to reduce the tin that may be oxydated. Any inflammable substance, as

oil for instance, will have, in some degree, the same effect, which is owing to their attraction for oxygen.

Tinning of Copper.—Sheets of copper may be tinned in the same manner as iron. Copper boilers, saucepans, and other kitchen utensils, are tinned after they are made. They are first scoured, then made hot, and the tin rubbed on as before with resin. Nothing ought to be used for this purpose but pure grain tin; but lead is frequently mixed with the tin, both to adulterate its quality and make it lay on more easily; but it is a very pernicious practice, and ought to be severely reprobated.

To whiten Brass or Copper by Boiling.—Put the brass or copper into a pipkin with some white tartar, alum, and grain tin, and boil them together: the articles will soon become covered with a coating of tin, which, when well polished, will look like silver. It is in this manner that pins and many sorts of buttons are whitened.

Bronzing.—Bronzing is colouring plaster, or other busts and figures, with metallic powders, in order to make them appear as if made of copper or other metals. The powders used for this purpose are either fine copper filings, aurum musivum, or copper precipitated from its solution in aquafortis by iron. Having done over the substance to be bronzed with either isinglass size, japanners' gold size, or, in some cases, with drying oil or oil-paint, the powders are rubbed on, taking care that the projecting parts receive more of the powder than the cavities, to imitate the brightness on those parts of bronze which are liable to be rubbed.

Soldering.—Soldering is the art of joining two pieces of metal together by heating them, with a thin piece or plate of metal interposed between them. Thus tin is a solder for lead; brass, gold, or silver, are solders for iron, &c.

To make Silver Solder.—Melt fine silver two parts, brass one part; do not keep them long in fusion, lest the brass fly off in fumes.

Another for coarser Silver.—Melt four parts of fine silver, and three of brass; throw in a little borax, and put it out as soon as it is melted.

A Solder for Gold.—Melt copper one part, fine silver one part, and gold two parts; add a little borax when it is just melted, then pour it out immediately.

The Method of soldering Gold or Silver.—After the solder is cast into an ingot, it would be more ready for use if you were to draw it into small wire, or flat it between two rollers; after that cut it into little bits, then join your work together with fine soft iron wire, and with a camel's-hair pencil dipt in borax finely powdered, and well moistened with water, touch the joint intended to be soldered; placing a little solder upon the joint, apply it upon a large piece of charcoal, and, with a blow-pipe and lamp, blow upon it through the flame until it melts the solder, and it is done.

To cleanse Silver or Gold after it is soldered.—Make it just red hot, and let it cool, then boil it in alum water, in an earthen vessel, and it will be as clean as when new. If gold, boil it in urine and sal-ammoniac

A Solder for Lead.—Two parts lead and one part tin: its goodness

is tried by melting it, and pouring the bigness of a crown-piece upon the table; if it be good, there will arise little bright stars in it. Apply resin when you use this solder.

A Solder for Tin.—Take four parts of pewter, one of tin, and one of bismuth; melt them together, and run them into narrow thin lengths.

A Solder for Iron.—Nothing here is necessary but good tough brass with borax applied, mixed with water to the consistence of paste.

CHAP. XIV.

MOULDING AND CASTING.

The art of taking casts or impressions from pieces of sculpture, medals, &c. is of very great importance in the fine arts.

In order to procure a copy or cast from any figure, bust, medal, &c. it is necessary to obtain a mould, by pressing upon the thing to be moulded or copied, some substance, which, when soft, is capable of being forced into all the cavities or hollows of the sculpture. When this mould is dry and hard, some substance is poured into it, which will fill all the cavities of the mould, and represent the form of the original from which the mould was taken.

The particular manner of moulding depends upon the form of the subject to be worked upon. When there are no projecting parts but such as form a right or a greater angle with the principal surface of the body, nothing more is required than to cover it over with the substance of which the mould is to be formed, taking care to press it well into all the cavities of the original, and to take it off clean, and without bending.

The substances used for moulding are various, according to the nature and situation of the sculpture. If it may be laid horizontally, and will bear to be oiled without injury, plaster of Paris may be advantageously employed, which may be poured over it to a convenient thickness, after oiling it to prevent the plaster from sticking. A composition of bees-wax, resin, and pitch, may also be used, which will be a very desirable mould if many casts are to be taken from it. But if the situation of the sculpture be perpendicular, so that nothing can be poured upon it, then clay, or some similar substance, must be used. The best kind of clay for this purpose is that used by the sculptors for making their models with; it must be worked to a due consistence, and having spread it out to a size sufficient to cover all the surface, it must be sprinkled over with whiting, to prevent it from adhering to the original. Bees-wax and dough, or the crumb of new bread, may also be used for moulding some small subjects.

When there are under-cuttings in the bas-relief, they must be first filled up before it can be moulded, otherwise the mould could not be got off. When the casts are taken afterwards, these places must be worked out with a proper tool.

When the model, or original subject, is of a round form, or projects so much that it cannot be moulded in this manner, the mould must be

divided into several parts; and it is frequently necessary to cast several parts separately, and afterwards to join them together. In this case, the plaster must be tempered with water to such a consistence that it may be worked like soft paste, and must be laid on with some convenient instrument, compressing it so as to make it adapt itself to all parts of the surface. When the model is so covered to a convenient thickness, the whole must be left at rest till the plaster is set and firm, so as to bear dividing without falling to pieces, or being liable to be put out of its form by any slight violence; and it must then be divided into pieces, in order to its being taken off from the model, by cutting it with a knife with a very thin blade; and being divided, must be cautiously taken off, and kept till dry: but it must be observed, before the separation of the parts be made, to notch them across the joints, or lines of division, at proper distances, that they may with ease and certainty be properly put together again. The art of properly dividing the moulds, in order to make them separate from the model, requires more dexterity and skill than any other thing in the art of casting, and does not admit of rules for the most advantageous conduct of it in every case. Where the subject is of a round or spheroidal form, it is best to divide the mould into three parts, which will then easily come off from the model; and the same will hold good of a cylinder, or any regular curve figure.

The mould being thus formed, and dry, and the parts put together, it must be first oiled, and placed in such a position that the hollow may lie upwards, and then filled with plaster mixed with water; and when the cast is perfectly set and dry, it must be taken out of the mould, and repaired when necessary, which finishes the operation.

In larger masses, where there would otherwise be a great thickness of the plaster, a core may be put within the mould, in order to produce a hollow in the cast, which both saves the expence of the plaster, and renders the cast lighter.

In the same manner, figures, busts, &c. may be cast of lead, or any other metal in the moulds of plaster or clay; taking care, however, that the moulds be perfectly dry; for should there be any moisture, the sudden heat of the metal would convert it into vapour, which would produce an explosion by its expansion, and blow the melted metal about.

To take a Cast in Metal from any small Animal, Insect, or Vegetable.—Prepare a box of four boards, sufficiently large to hold the animal, in which it must be suspended by a string, and the legs, wings, &c. of the animal, or the tendrils, leaves, &c. of the vegetable, must be separated, and adjusted in their right position by a pair of small pincers. A due quantity of plaster of Paris mixed with talc, must be tempered to the proper consistence with water, and the sides of the box oiled. Also a straight piece of stick must be put to the principal part of the body, and pieces of wire to the extremities of the other parts, in order that they may form, when drawn out after the matter of the mould is set and firm, proper channels for pouring in the metal, and vents for the air, which otherwise, by the rarefaction it would undergo from the heat of the metals, would blow it out, or burst the mould. In a short time the plaster will set, and become hard; when the stick and wires may be drawn out, and the frame or coffin in which the mould was cast

taken away; and the mould must then be put, first, into a moderate heat, and, afterwards, when it is as dry as can be rendered by that degree, removed into a greater, which may be gradually increased, till the whole be red hot. The animal or vegetable inclosed in the mould will then be burnt to a coal; and may be totally calcined to ashes, by blowing for some time into the charcoal and passages made for pouring in the metal, and giving vent to the air, which will, at the same time that it destroys the remainder of the animal or vegetable matter, blow out the ashes. The mould must then be suffered to cool gently, and will be perfect; the destruction of the substance included in it, having produced a corresponding hollow; but it may nevertheless be proper to shake the mould, and turn it upside down, as also to blow with the bellows into each of the air vents, in order to free it wholly from any remainder of the ashes; or where there may be an opportunity of filling the hollow with quick-silver, it will be found a very effectual method of clearing the cavity, as all dust, ashes, or small detached bodies, will necessarily rise to the surface of the quicksilver, and be poured out with it. The mould being thus prepared, it must be heated very hot, when used, if the cast is to be made with copper or brass, but a less degree will serve for lead or tin. The metal being poured into the mould, must be gently struck, and then suffered to rest till it be cold; at which time it must be carefully taken from the cast, but without force; for such parts of the matter as appear to adhere more strongly, must be softened, by soaking in water till they be entirely loosened, that none of the more delicate parts of the cast may be broken off or bent.

When talc cannot be obtained, plaster alone may be used; but it is apt to be calcined, by the heat used in burning the animal or vegetable from whence the cast is taken, and to become of too incoherent and friable a texture. Stourbridge, or any other good clay, washed perfectly fine, and mixed with an equal part of fine sand, may be employed. Pounded pumice-stone, and plaster of Paris, in equal quantities mixed with washed clay in the same proportion, is said to make excellent moulds.

Method of taking a Cast in Plaster from a Person's Face.—The person whose likeness is required in plaster, must lie on his back, and the hair must be tied back, so that none of it covers the face. Into each nostril convey a conical piece of stiff paper open at both ends, to allow of breathing. The face is then lightly oiled over in every part with salad-oil, to prevent the plaster from sticking to the skin. Procure some fresh burnt plaster, and mix it with water to a proper consistence for pouring. Then pour it by spoonfuls quickly all over the face (taking care the eyes are shut), till it is entirely covered to the thickness of a quarter of an inch. This substance will grow sensibly hot, and in a few minutes will be hard. This being taken off, will form a mould, in which a head of clay may be moulded, and therein the eyes may be opened, and such other additions and corrections may be made as are necessary. Then, this second face being anointed with oil, a second mould of plaster must be made upon it, consisting of two parts joined lengthwise along the ridge of the nose; and in this a cast in plaster may be taken, which will be exactly like the original.

To take Casts from Medals.—In order to take copies of medals, a

mould must first be made; this is generally either of plaster of Paris, or of melted sulphur.

After having oiled the surface of the medal with a little cotton, or a camel's-hair pencil dipped in oil of olives, put a hoop of paper round it, standing up above the surface of the thickness you wish the mould to be. Then take some plaster of Paris, mix it with water to the consistence of cream, and with a brush rub it over the surface of the medal, to prevent air-holes from appearing; then immediately afterwards make it to a sufficient thickness, by pouring on more plaster. Let it stand about half an hour, and it will in that time grow so hard, that you may safely take it off; then pare it smooth on the back and round the edges neatly. It should be dried, if in cold or damp weather, before a brisk fire. If you cover the face of the mould with fine plaster, a coarser sort will do for the back: but no more plaster should be mixed up at one time than can be used, as it will soon get hard, and cannot be softened without burning over again.

Sulphur must not be poured upon silver medals, as this will tarnish them.

To prepare this mould for casting sulphur or plaster of Paris in, take half a pint of boiled linseed-oil, and oil of turpentine one ounce, and mix them together in a bottle; when wanted, pour the mixture into a plate or saucer, and dip the surface of the mould into it; take the mould out again, and when it has sucked in the oil, dip it again. Repeat this till the oil begins to stagnate upon it; then take a little cotton wool, hard rolled up, to prevent the oil from sticking to it, and wipe it carefully off. Lay it in a dry place for a day or two (if longer the better), and the mould will acquire a very hard surface from the effect of the oil.

To cast plaster of Paris in this mould, proceed with it in the same manner as above directed for obtaining the mould itself, first oiling the mould with olive-oil. If sulphur casts are required, it must be melted in an iron ladle.

Another method with Isinglass.—Dissolve isinglass in water over the fire: then with a hair pencil lay the melted isinglass over the medal, and when you have covered it properly, let it dry. When it is hard, raise the isinglass up with the point of a knife, and it will fly off like horn, leaving a sharp impression of the medal.

The isinglass may be made of any colour by mixing the colour with it, or you may breathe on the concave side, and lay gold leaf on it, which by shining through will make it appear like a gold medal. But if you wish to imitate a copper medal, mix a little carmine with the isinglass, and lay gold leaf on as before.

CHAP. XV.

CALICO PRINTING.

Calico Printing is the art of communicating different colours to particular spots or figures on the surface of cotton or linen cloth, while the rest of the stuff retains its original whiteness.

This ingenious art seems to have originated in India, where it has been practised for more than two thousand years. No art has arisen to perfection with greater celerity. A hundred years ago it was scarcely known in Europe; at present the elegance of the patterns, the beauty and permanency of the colours, and the expedition with which the different operations are carried on, are really admirable

Calico printing consists in impregnating those parts of the cloth which are to receive a colour, with a mordant, and then dyeing it as usual with some dye stuff or other. The dye stuff attaches itself firmly only to that part of the cloth which has received the mordant. The whole surface of the cotton is indeed more or less tinged, but by washing it, and bleaching it for some days on the grass, with the wrong side uppermost, all the unmordanted parts resume their original colour, while those which have received the mordant retain it. Let us suppose that a piece of white cotton cloth is to receive red stripes; all the parts where the stripes are to appear are pencilled over with a solution of acetite of alumine; after this, the cloth is dyed in the usual manner with madder. When taken out of the dyeing vessel it is all of a red colour, but by washing and bleaching, the madder leaves every part of the cloth white, except the stripes impregnated with the acetite of alumine, which remain red. In the same manner may yellow stripes, or any other wished-for figure, be given to cloth, by substituting quercitron bark, weld, &c. for madder.

When different colours are to be given to different parts of the cloth at the same time, it is done by impregnating it with various mordants. Thus, if stripes be drawn upon a cotton cloth with acetite of alumine, and other stripes with acetite of iron, and the cloth be afterwards dyed in the usual way with madder, and then washed and bleached, it will be striped red and brown. The same mordants with quercitron bark, give yellow, and olive, or drab.

The mordants employed in calico printing are acetite of alumine, and acetite of iron, prepared in the manner described. These mordants are applied to the cloth, either with a pencil, or by means of blocks, on which the pattern, according to which the cotton is to be printed, is cut. As they are applied only to particular parts of the cloth, care must be taken that none of them spread to the part of the cloth which is to be left white, and that they do not interfere with one another when more than one are applied. If these precautions be not attended to, all the elegance and beauty of the print must be destroyed. It is necessary, therefore, that the mordants should be of such a degree of consistence, that they will not spread beyond those parts of the cloth on which they are applied. This is done by thickening them with flour or starch, when they are to be applied by the block; and with gum-arabic, when they are to be put on by a pencil. The thickening should

never be greater than is sufficient to prevent the spreading of the mordants; when carried too far, the cotton is apt not to be sufficiently saturated with the mordants; of course the dye takes but imperfectly.

In order that the parts of the cloth impregnated with mordants may be distinguished by their colour, it is usual to tinge the mordants with some colouring matter or other. The printers commonly use the decoction of Brazil-wood for this purpose; but Dr. Bancroft has objected to this method, because he thinks that the Brazil-wood colouring matter impedes the subsequent process of dyeing. It is certain, that the colouring matter of the Brazil-wood is displaced during that operation, by the superior affinity of the dye stuff for the mordants. Were it not for this superior affinity, the colour would not take at all. Dr. Bancroft advises to colour the mordant with some of the dye stuff afterwards to be applied; and he cautions the using of more for that purpose, than is sufficient to make the mordant distinguishable when applied to the cloth. The reason of this precaution is obvious. If too much dye be mixed with the mordant, a great proportion of the mordant will be combined with colouring matter, which must weaken its affinity for the cloth, and of course prevent it from combining with it, in sufficient quantity to ensure a permanent dye.

Sometimes these two mordants are mixed together in different proportions; aud sometimes one or both is mixed with an infusion of sumach, or of nut-galls. By these contrivances, a great variety of colours are produced by the same dye stuff.

After the mordants have been applied, the cloth must be completely dried. It is proper for this purpose to employ artificial heat, which will contribute something towards the separation of the acetous acid from its base, and towards its evaporation, by which the mordant will combine in a greater proportion, and more intimately with the cloth.

When the cloth is sufficiently dried, it is to be washed with warm water and cow-dung, till all the flour, or gum, employed to thicken the mordants, and all those parts of the mordants which are uncombined with the cloth, be removed. The cow-dung serves to entangle these loose parts of the mordants, and to prevent them from combining with those parts of the cloth which are to remain white. After this, the cloth is thoroughly rinsed in clean water. Almost the only dye stuffs employed by calico printers, are indigo, madder, and quercitron bark, or weld. This last substance, however, is but little used by the printers of this country, except for delicate greenish yellows. The quercitron bark has almost superseded it, because it gives colours equally good, and is much cheaper and more convenient, not requiring so great a heat to fix it. Indigo not requiring any mordant, is commonly applied at once, either with a block or a pencil. It is prepared by boiling together indigo, potass made caustic by quick-lime, and orpiment; the solution is afterwards thickened with gum. It must be carefully secluded from the air, otherwise the indigo would soon be regenerated, which would render the solution useless. Dr. Bancroft has proposed to substitute coarse brown sugar for orpiments: it is equally efficacious in decomposing the indigo, and rendering it soluble; while it likewise serves all the purposes of gum.

When the cloth, after being impregnated with the mordant, is sufficiently cleansed, it is dyed in the usual manner. The whole of it is more or less tinged with the dye stuff. It is well washed, and then spread

out for some days on the grass, and bleached with the wrong side uppermost. This carries the colour off completely from all the parts of the cotton which have not imbibed the mordant, and leaves them of their original whiteness, while the mordanted spots retain the dye as strongly as ever.

Let us now give an example or two of the manner in which the printers give particular colours to calicoes. Some calicoes are only printed of one colour; others have two, others three or more, even to the number of eight, ten, or twelve. The smaller the number of colours, the fewer in general are the processes.

1. One of the most common colours on cotton prints is a kind of nankeen yellow, of various shades down to a deep yellowish brown, or drab. It is usually in stripes or spots. To produce it, the printers besmear a block, cut out into the figure of the print, with acetite of iron, thickened with gum or flour; and then apply it to the cotton, which, after being dried and cleaned in the usual manner, is plunged into a potass ley. The quantity of acetite of iron is always proportioned to the depth of the shade.

2. For yellow, the block is besmeared with acetite of alumine. The cloth, after receiving this mordant, is dyed with quercitron bark, and then bleached.

3. Red is communicated by the same process; only madder is substituted for the bark.

4. The fine light blues which appear so often on printed cottons, are produced by applying to the cloth, a block besmeared with a composition, consisting partly of wax, which covers all those parts of the cloth which are to remain white. The cloth is then dyed in a cold indigo vat; and after it is dry, the wax composition is removed by hot water.

5. Lilac flea brown, and blackish brown, are given by means of acetite of iron; the quantity of which is always proportioned to the depth of the shade. For very deep colours, a little sumach is added. The cotton is afterward dyed in the usual manner with madder, and then bleached.

6. Dove colour and drab, by acetite of iron and quercitron bark.

When different colours are to appear in the same print, a greater number of operations are necessary. Two or more blocks are employed, upon each of which, that part of the print only is cut, which is to be of some particular colour. These are besmeared with different mordants, and applied to the cloth, which is afterwards dyed as usual. Let us suppose, for instance, that these blocks are applied to cotton, one with acetite of alumine, another with acetite of iron, a third with a mixture of those two mordants, and that the cotton is then dyed with quercitron bark, and bleached. The parts impregnated with the mordants would have the following colours:

Acetite of alumine,	Yellow.
———— iron,	Olive, drab, dove.
The mixture,	Olive green, olive.

If part of the yellow be covered over with the indigo liquor, applied with a pencil, it will be converted into green. By the same liquid, blue may be given to such parts of the print as require it.

If the cotton be dyed with madder, instead of quercitron bark, the print will exhibit the following colours:

Acetite of alumine,	Red
——— iron,	Brown, black.
The mixture,	Purple.

When a greater number of colours are to appear; for instance, when those communicated by bark, and those by madder, are wanted at the same time, mordants for part of the pattern are to be applied; the cotton is then to be dyed in the madder bath, and bleached; then the rest of the mordants, to fill up the pattern, are added, and the cloth is again dyed with quercitron bark, and bleached. The second dyeing does not much affect the madder colours; because the mordants, which render them permanent, are already saturated. The yellow tinge is easily removed by the subsequent bleaching. Sometimes a new mordant is also applied to some of the madder colours, in consequence of which, they receive a new permanent colour from the bark. After the last bleaching, new colours may be added by means of the indigo liquor. The following table will give an idea of the colours which may be given to cotton by these complicated processes:

I. *Madder Dye.*

Acetite of alumine,	Red
——— iron,	Brown, black.
——— diluted,	Lilac.
Both mixed,	Purple.

II. *Bark Dye.*

Acetite of alumine,	Yellow.
——— iron,	Dove, drab.
Lilac and acetite of alumine,	Olive.
Red and acetite of alumine,	Orange.

III. *Indigo Dye.*

Indigo,	Blue.
Indigo and yellow,	Green.

Thus no less than 12 colours may be made to appear together in the same print, by these different processes.

These instances will serve to give the reader an idea of the nature of calico printing, and at the same time afford an excellent illustration of the importance of mordants in dyeing.

If it were possible to procure colours sufficiently permanent, by applying them at once to the cloth by the block or the pencil, as is the case with the mordants, the art of calico printing would be brought to the greatest possible simplicity; but at present, this can only be done in one case, that of indigo; every other colour requires dyeing. Compositions, indeed, may be made, by previously combining the dye stuff and the mordants. Thus yellow may be applied at once, by employing a mixture of the infusion of quercitron bark and acetite of alumine; red, by mixing the same mordant with the decoction of alumine, and so on. The colours applied in this way, are, unfortunately, far inferior in permanency to those produced when the mordant is previously combined with the cloth, and the dye stuff afterwards applied separately.

In this way are applied almost all the fugitive colours of calicoes, which washing, or even exposure to the air, destroys.

As the application of colours in this way cannot always be avoided by calico printers, every method of rendering them more permanent is an object of importance.

CHAP. XVII.

BLEACHING.

The art of bleaching is of great antiquity. The ancients were acquainted with the detersive quality of some kinds of clay, and the effect produced by the action of the atmosphere, moisture, and light, on the stuffs exposed to them. Health and cleanliness rendered it necessary to devise quicker methods than these; and the property of soaps and leys of ashes was therefore soon discovered.

In the present age, the arts following science with close steps, have taken advantage of processes and detersive menstrua, the existence of which was before unknown; these discoveries have succeeded each other with such rapidity, that the last eight years have effected a complete revolution in the art of bleaching.

This art is naturally divided into two distinct branches; the bleaching of vegetable, and of animal substances. These being of very different natures, require different processes for whitening them. Vegetables, as has been already mentioned, consist of oxygen, hydrogen, and carbon, of which the latter is in the greatest proportion, while animal substances, besides these, contain also a large quantity of azote, and also phosphorus and sulphur.

Bleaching of Flax and Hemp.—If ripe flax or hemp be examined, they will be found to consist of a thin bark, enveloping a green sap; next, the fibres or filaments that are used in the making of linen; and within that, the woody part. As it is the fibrous part only that is used in the making of cloth, it is necessary to separate that from the other substances.

The sap, or succulent part, is composed of extractive principle and water, and the first process is to separate this substance, which holds the filaments together. As soon as the flax is pulled, it is steeped in soft water, until the putrefactive fermentation takes place. This degree of fermentation begins with the succulent part, as being more susceptible of fermentation than the rest. Were the flax to be continued long in this state, the whole substance of it would be decomposed and destroyed; it must therefore be taken out of the water when the wood breaks easily between the hands, while it is yet green, and before the whole of its sap is separated. Well water, and brackish water, as well as that which flows over gypseous soil, must be carefully avoided, as such water accelerates putrefaction, and would injure the texture of the fibres. It is thus that a little salt accelerates animal putrefaction, while a great deal tends to prevent it; and the portion of saline sub-

stances held in solution in the water hastens the corruption of the filaments which it blackens and spoils.

This operation of watering is long and noxious, as it is found to destroy the fish in any stream that may be used, and the smell of the putrifying plants is extremely offensive. It is one of the improvements of the manufacture by modern chemistry to shorten this process, and to perform it with less risk of injuring the flax. If the steam of a solution of caustic alkali in water be introduced into a chamber of from 20 to 30 feet square, in which the flax is suspended, it will produce the same effect as watering, in less time, and with less expence; and also with less danger to the flax, which is frequently injured by too long steeping.

Nothing remains after the watering is completed, but the woody part (which is a hollow tube), covered over very compactly with the flax. To separate these, it must be kiln-dried to render it brittle or frangible, but care must be taken not to apply too much heat.

It is next to be beat or broke, either by manual labour with mallets on a sort of wooden anvils, as in the houses of correction, or by mills for the purpose. The flax is by this means divided into small fibres, and most of the wood separated or reduced to small fragments, which are cleared away by scutching or threshing.

Hackling is the last process, which is nothing more than drawing or combing the flax in small parcels at a time, through a pile or group of polished and sharp iron spikes, placed firmly in wood. The spikes are placed pretty close together; the first hackle is coarse, the second finer, and the third finer again. The process of hackling answers several purposes; first it divides the fibres of the flax from each together; secondly it detaches the minute fragments of wood which escaped the process of scutching; and lastly, it separates the short coarse flax commonly called the tow.

The flax is then ready to be spun into thread or yarn, which is afterwards manufactured into cloth by the weaver.

It is now that the process of bleaching begins. The linen as it comes from the loom is charged with the weaver's dressing, which is a paste of flour and water brushed into the yarn of the work, to render the stretching of it more easy. To discharge this paste, the linen must be steeped in water for forty-eight hours, till the extraneous substance is decomposed by fermentation, which does not extend to the linen itself. Some bleachers boil the linen in water; but improperly, as paste is not soluble in boiling water.

When the linen is well washed and rinsed after the last process, it is of a greyish white colour, although the fibres of which it is composed are naturally very white.

To separate the matter that discolours the linen is the business of bleaching. This grey substance is of a resinous nature, insoluble in water, and from its intimate union or dissemination through the very fibres of the flax, is difficult of separation, even by those substances that have a solvent power over it.

Alkaline leys, or solutions of alkali rendered caustic, have the property of dissolving resins: hence they have been employed as menstrua for this purpose. But alone they are not sufficient for completing the process of bleaching. What appears to be a single ultimate fibre of flax in grey linen, is composed of a bundle of minute filaments, closely

cemented or agglutinated together by the resinous matter: therefore the potass first only acts upon the resin of the external coating of filaments, by which means they are loosened or separated, and exposed to the further action of the air. The second boiling of potass opens a second layer, and thus successively layer after layer, until the whole is divided or opened to the centre. Were the alkaline solution sufficiently strong to force its way at once to the centre, it would act upon the filaments themselves, and destroy the texture of the cloth. Each filament, after the alkaline process, retains an impregnation of colouring matter, so intimately united as to resist the further action of it. This can only be removed by the slow and gradual influence of the atmosphere, according to the old method of bleaching, or by the modern improvement of using the oxygenated muriatic acid.

To explain the principle upon which this latter part of the process is effected, we must consider that the resin, which forms the colouring matter of unbleached linen, is composed chiefly of carbon and hydrogen; this is partly dissolved by the alkaline ley, and what remains becomes united to the oxygen of the atmosphere; flying off in the state of carbonic acid gas, or remaining as water.

The great objection to the old manner of bleaching is its tediousness, two or three months being requisite to give the cloth the necessary whiteness. The simplicity of it and the little apparatus it requires, recommend it, however, on some occasions, and accordingly it is employed by those country people who make their own cloth, particularly in Scotland.

Method of bleaching by the action of the atmospheric air.—After steeping the linen as above-mentioned, to remove the weaver's dressing, the pieces are dried, and then submitted to the operation of bucking. For this purpose a ley is prepared by dissolving a quantity of potass in soft water, to which is added some soap. It is most economical to render it caustic for the purpose of bleaching. This is done by adding quicklime to the mild potass, the former having a stronger affinity for the carbonic acid than the latter. But care must be taken not to use the alkali too strong. This liquor is heated to about 100 degrees, and poured upon the pieces of linen. After the cloth is well down in the ley, it is drawn off, heated a little higher, and again poured upon the cloth. This operation is repeated at intervals, allowing the ley to remain longer each succeeding time, and moderately increasing the heat, for five or six hours. Then the cloth is left steeping for three or four hours, when it is taken out, well rinsed, and carried to the field. Here it is spread upon the grass, and secured by pins; water is sprinkled on it, so as not to allow it to become dry for some hours. After it has lain about half a day, the watering is less frequent, and at night it is left to the full action of the air and dews. On the succeeding days it is watered three or four times a day, if the weather be dry, and then it remains on the field till the air seems to have less effect in whitening. It is then brought back to the coppers and bucked again, with a ley somewhat stronger than the last, rinsed, and again spread out in the field. It is thus alternately bucked and watered ten or fifteen times, according to the weather, making the bucking stronger and stronger, till about the middle, and then weaker and weaker till towards the last.

It must now undergo the process of souring or steeping in some acid liquor. The acid which has been usually employed for the process of

souring is formed by the fermentation of bran and water; or sometimes sour whey has been used. But sulphuric acid, very much diluted, has been found more convenient, and not more injurious. The cloths are kept in the souring for five or six days, if it be formed of milk or bran, or a less time when the sulphuric acid is used. They are then rubbed with soap, more particularly the selvages, as these resist most the action of the air. The cloth is now again bucked, rinsed, watered, and exposed to the air, and these processes are repeated successively, till the linen has acquired the necessary whiteness.

Bleaching by the Oxygenated Muriatic Acid.—The oxygenated muriatic acid gas, and its property of destroying colours, have been already described under chemistry. This combined with water, forms the oxygenated muriatic acid, which is therefore only a combination of muriatic acid and oxygen. All vegetable colours are attacked by this acid, and whitened with more or less celerity; the colouring matter undergoes a real slow combustion, terminating by the formation of carbonic acid gas, which escapes into the atmosphere. In whatever manner the oxygenated muriatic acid is procured, it is evident that the oxygen adheres to it only weakly, and it is upon this property that the possibility depends of producing speedily in manufactories, that action which the atmosphere produces but slowly, and of bleaching in a time proportionably short.

The oxygenated muriatic acid is employed in four different ways for the purposes of bleaching; first, in the state of gas alone; secondly, in the state of gas combined with water, or what is called the acid; thirdly, potass is mixed with the acid to condense the gaseous vapour and destroy its suffocating odour; fourthly, oxygenated muriates, dissolved in water, are employed.

The first method, viz. employing the gas, was never used but for the purpose of experiment; as the vapour is of so noxious a quality, that to breathe it is fatal, and several people fell a sacrifice to their attempts in employing it.

When condensed in water, or in the state of oxygenated muriatic acid, it was found inconvenient in the large way, on account of the expence and difficulty in constructing the necessary apparatus, and the suffocating vapour which escaped.

For the discovery of the oxygenated muriatic acid, its effects on colouring matter, and its inestimable advantages, the arts are indebted to the justly celebrated Scheele. M. Berthollet lost no time in applying this curious and highly interesting substance to the most important practical uses. His experiments of bleaching by oxygenated muriatic acid, proved completely successful, and he did not delay to communicate his valuable labours to the public. The new method of bleaching was quickly and successfully introduced into the manufactories of Manchester, Glasgow, Rouen, Valenciennes, and Courtrary; and it has since been generally adopted in Great Britain, Ireland, France, and Germany. The advantages that result from this method, which accelerates the process of whitening cottons, linens, paper, &c. to a really surprising degree, in every season of the year, can be justly appreciated by commercial people only, who experience its beneficial effects in many ways, but particularly in the quick circulation of their capitals.

The methods of procuring this acid have been already mentioned. To save the expence of first preparing the muriatic acid, the

usual practice is to mix with the oxyde of managanese, muriate of soda or common salt, and sulphuric acid diluted with water. The sulphuric acid acts upon the salt, and disengages from it the muriatic acid, which is oxygenated by the oxyde of manganese. The proportions observed when cotton is to be bleached, are,

Manganese, - - - - - -	30 parts
Common salt, - - - - -	80
Sulphuric acid, - - - - -	60
Water, - - - - -	120

For linen-cloth the proportions are as follow:

Manganese, - - - - -	60 parts
Salt, - - - - - - -	60
Sulphuric acid, - - - - -	50
Water, - - - - - -	50

The better these substances are combined together, the more easily will the acid gas be disengaged by the action of the sulphuric acid.

To ascertain the strength of the acid for bleaching, a solution of indigo in the sulphuric acid is employed. The colour of this is destroyed by the oxygenated muriatic acid, and according to the quantity of it that can be discoloured by a given quantity of the liquor, its strength is known.

Cloth is prepared for immersion in oxygenated water, by soaking in a ley of weak potass, and rinsing it afterwards in a large quantity of water, in order to free it completely from the weaver's dressing, and the saliva of the spinners.

In this country, machinery is employed for rinsing and beating; the apparatus must be arranged according to the objects to be bleached; the skeins of thread must be suspended in the tub destined for them, and the cloth must be rolled upon reels in the apparatus. When every thing is thus disposed, the tubs are filled with oxygenated muriatic acid, by introducing a funnel, which descends to the bottom of the tub, in order to prevent the dispersion of the gas. The cloth is wound, or the frame work on which the skeins are suspended, is turned several times, until it is judged, by taking out a small quantity of the liquor from time to time, and trying it by the test of the solution of indigo, that it is sufficiently exhausted. The weakened liquor is then drawn off, and may be again employed for a new saturation.

Great difficulties for a time impeded the progress of this method of bleaching, arising chiefly from prejudice, and the ignorance of bleachers in chemical processes. These obstacles were, however, soon removed by Mr. Watt of Glasgow, and by Mr. Henry and Mr. Cooper at Manchester. Another difficulty presented itself, which had nearly proved fatal to the success of the operation. This was the want of a proper apparatus, not for making the acid, and combining it with water, for this had been supplied in a very ingenious manner by Mr. Watt and M. Berthollet; but for the purpose of immersing and bleaching goods in the liquor. The volatility of this acid, and its suffocating vapours, prevented its application in the way commonly used in dye-houses. Large cisterns were therefore constructed, in which pieces of stuff were stratified; and the liquor being poured on them, the cisterns were

closed with lids. But this method was soon found to be defective, as the liquor could not be equally diffused; the pieces were therefore only partially bleached, being white in some parts, and more or less coloured in others.

Mr. Rupp, of Manchester, invented an apparatus for bleaching cloth, exceedingly simple in its construction, of small expence, and which contains the liquor in such a manner as to prevent the escape of the oxygenated muriatic acid gas. A consideration of no less importance in the arrangement of this apparatus, is the impossibility of the vapour injuring the health of the workmen.

It was found, however, that the use of the oxygenated muriatic acid alone weakened the cloth, and various methods of preventing its noxious effects upon the health of the workmen were tried without success, till it was discovered that an addition of alkali to the liquor deprived it of its suffocating effects, without destroying its bleaching powers. The process began then to be carried on in open vessels, and has been continued in this manner to the present period. The bleacher is now able to work his pieces in the liquor, and to expose every part of them to its action, without inconvenience.

Potass was at first used for this purpose; and although this advantage was unquestionably great, it was diminished by the heavy expence of the alkali, which was entirely lost. Also, the potass which was added to the liquor, though it did not destroy its power of bleaching, diminished it, because a solution of the oxygenated muriate of potass, which differs from this bleaching liquor in nothing but in the proportion of alkali, will not bleach at all. This is a well-known fact, from which we might infer, that the oxygenated muriatic acid will lose its power of destroying the colouring matter of vegetable substances, in proportion as it becomes neutralized by potass.

It was afterwards discovered that the oxymuriatic acid might be combined with the alkaline earths, as lime and barytes, and also with magnesia, by this means forming oxymuriates, which were soluble in water and had the property of bleaching. The oxymuriate of lime is at present used in almost all the bleaching grounds. For the manner of preparing it, Mr. Tennant took out a patent; but this has been lately contested, and it is now prepared and used by all the bleachers through the country.

If the oxygenated muriatic acid be passed through lime water, it will combine with the lime, and form oxymuriate of lime; but as the water can only retain a small portion of lime, this was not found of much use. To cause a larger quantity of lime to combine with the oxymuriatic acid gas, the lime is mechanically suspended in the water, into which the gas is made to pass, and agitated, so as to present fresh matter to the gas. By this means, the oxymuriate of lime is formed in a very convenient manner; it is dissolved in water, and used as a bleaching liquor.

This liquor is found to be preferable to the oxygenated muriatic acid and potass. At the great bleach-fields in Ireland, four leys of potass are applied alternately with four weeks exposure on the grass, two immersions in the oxygenated muriate of lime, a ley of potass between the two, and the exposure of a week on the grass, between each ley and the immersions. During summer, two leys and fifteen days exposure are sufficient to prepare cloth for the action of the oxygenated

muriate; then three alternate leys, with immersions in the liquor, will be sufficient for complete bleaching: nothing then will be necessary, but to wind the cloth through the sulphuric acid.

The oxygenated muriatic acid gas may also be combined with lime in a dry state, or the water may be evaporated, when it is employed for the formation of oxymuriates, which may then be very conveniently transported to any distance without injury to its detersive power; an advantage not possessed by the acid alone, which cannot be transported without the loss of almost half of its strength.

The sulphuret of lime or the combination of sulphur and lime, which are both cheap articles, has been proposed by Mr. Higgins to answer the purposes of potass in bleaching; and it is certainly useful in some cases, though in others it will not supersede the use of alkali.

The sulphuret of lime is prepared in the following manner, for the purpose of bleaching:—Sulphur or brimstone, in fine powder, four pounds; lime, well slaked and sifted, twenty pounds; water, sixteen gallons; these are to be well mixed, and boiled for about half an hour in an iron vessel, stirring them briskly from time to time. Soon after the agitation of boiling is over, the solution of the sulphuret of lime clears, and may be drawn off free from the insoluble matter, which is considerable, and which rests upon the bottom of the boiler. The liquor, in this state, is pretty nearly of the colour of small-beer, but not quite so transparent.

Sixteen gallons of fresh water are afterwards to be poured upon the insoluble dregs in the boiler, in order to separate the whole of the sulphuret from them. When this clears (being previously well agitated), it is also to be drawn off, and mixed with the first liquor; to these again thirty-three gallons more of water may be added, which will reduce the liquor to a proper standard for steeping the cloth. Here we have (an allowance being made for evaporation, and for the quantity retained in the dregs) sixty gallons of liquor from four pounds of brimstone.

Although sulphur, by itself, is not in any sensible degree soluble in water, and lime but sparingly so, water dissolving only about one seven-hundredth part of its weight of lime; yet the sulphuret of lime is highly soluble.

When linen is freed from the weaver's dressing, in the manner already described, it is to be steeped in the solution of sulphuret of lime (prepared as above) for about twelve or eighteen hours, then taken out and very well washed. When dry, it is to be steeped in the oxymuriate of lime for twelve or fourteen hours, and then washed and dried. This process is to be repeated six times, that is, six alternate immersions in each liqour which has been found to whiten the linen.

The rationale of these processes is the following: The oxygenated liquor supplies to the cloth the place of the atmospheric air, and this in greater abundance, and in a state which renders its action on the cloth more expeditious and more complete. By the union of the oxygen with the carbon of the colouring matter of the cloth, carbonic acid is formed, and flies off.

Steam has been lately employed in bleaching with great success in France. The process was brought from the Levant. Chaptal first made it known to the public.

In the old processes, a long succession of leys, and exposure on the grass, was necessary to penetrate the fibres of the linen from stratum

to stratum. The texture was sufficiently close to resist the action of the heat of a common ley, and a considerable time was required to absorb the oxygen presented by the delicate stratum of atmospheric air.

In the process of bleaching by steam, these difficulties are removed. The high temperature of the steam, in the interior part of the apparatus, swells up the fibres of the thread or cloth ; the pure alkali, which rises with the elastic fluid, seizes with avidity on the colouring matter, and burns it ; seldom does the tissue of the flax or hemp resist the penetrating effect of this vapour bath. The whole matter, therefore, by which they are coloured, is attacked and decomposed by this single operation ; and even if we suppose that a part has been able to resist, nothing is necessary but to repeat the operation, after a previous immersion and exposure on the grass, to ensure its complete effect. The alkali even appears to have a much livelier and more caustic action, when it is combined with caloric, than in ordinary leys, where the temperature never rises above 162° of Fahrenheit. By making the cloth or thread pass through one ley of oxygenated muriatic acid, or oxygenated muriate of lime, an union is effected between the solution and the carbon, arising from the burning of the extracto-mucous matter of the flax ; carbonic acid is formed ; the water even in which this new compound is diluted, concurs to promote this combination ; if the cloth be then exposed on the grass, the carbonic acid is dissipated, and the cloth is bleached.

It was believed that the steam of a pure alkaline ley would not be caustic, and would not produce the same effects as the saline solution ; and the reason assigned for this opinion was, the concentration of all the salts by the evaporation of the aqueous fluid ; but what takes place in the open air, where the atmosphere every moment absorbs the moisture which is evaporated, cannot be applied to a close apparatus, where the temperature is elevated in an extreme degree ; besides, the caloric always carries with it a little alkali, even in low temperatures, as is observed when water is poured over potass ; the steam which issues from it changes blue vegetable colours to green.

The action of steam alone does not bleach, and the concurrence of oxygen is necessary to aid the composition of the carbonic acid ; this acid requires for its formation, 28 parts of carbon, saturated with 72 of oxygen ; but all the oxygen contained in the apparatus would not be sufficient to saturate the considerable quantity of colouring matter burnt by the alkaline combustion, and converted into carbon ; this deficit must be supplied by immersion in any oxygenated liquor whatever, and the dispersion of the elastic fluid thus formed must be then facilitated by exposure on the grass.

To bleach cloth in this manner, it must be immersed in a slight alkaline caustic liquor, and placed in a chamber constructed over a boiler, into which is put the alkaline ley which is to be raised into steam. After the fire has been lighted, and the cloth has remained exposed to the action of the steam for a sufficient length of time, it is taken out, and immersed in the oxygenated muriate of lime, and afterwards exposed for two or three days on the grass. This operation, which is very expeditious, will be sufficient for cotton ; but if linen cloth should still retain a yellow tint, a second alkaline caustic vapour bath, and two or three days on the grass, will be sufficient to give them the necessary degree of whiteness.

For the use of private families, when the linen is dirtied by perspiration or grease, it will be of great service towards rendering it white, to steep it for some time in a clear liquor, made by mixing one quart of quicklime in ten gallons of water, letting the mixture stand twenty-four hours, and then using the clean water drawn from the lime. After the linen has been steeped in this liquor, it should be washed as usual, but will require much less soap to be used.

Bleaching of Cotton.—Cotton is a filamentous substance, or a kind of down which envelopes the seeds of the cotton plant. This plant or shrub comes from the east, and grows only in warm climates.

This substance, after being separated from the seeds, is always charged with a coarse colouring matter, which soils it, and renders it opaque. The presence of this unctuous matter is proved by the slowness with which cotton absorbs water before it is scoured, and by the force with which it absorbs it after the operation; by which means, from being opaque, it is rendered clear and transparent.

Cotton varies a great deal in its qualities, according to the different kinds, the climate where produced, and the culture employed. Its colour is sometimes yellow, and sometimes white, but, in general, it is of a dirty yellow.

To bleach it, does not require the same preparations as hemp and flax. The first operation consists in scouring it in a slight alkaline solution, or, what is better, by exposure to steam. It is afterwards put into a basket, and rinsed in running water. The immersing of cotton in an alkaline ley, however it be rinsed, always leaves with it an earthy deposit. It is well known that cotton bears the action of acids better than hemp or flax; that time is even necessary before the action of them can be prejudicial to it, and by taking advantage of this valuable property in regard to bleaching, means have been found to free it from the earthy deposit, by pressing down the cotton in a very weak solution of sulphuric acid, and afterwards removing the acid by washing, lest too long remaining in it should destroy the cotton.

Bleaching of Wool.—The substances produced by the animal kingdom differ essentially in their constituent principles from vegetables. Vegetables serve as the nourishment to the animals and insects, the spoils of which we employ. Animalized by their organs, they acquire other properties. We shall here confine ourselves to the examination of wool and silk, as the animal substances most generally employed for clothing.

Wool is a kind of hair with which the bodies of several animals are covered. It is composed of filaments or tubes, filled with an oily or medullary substance. The sides of these tubes are perforated with a multitude of small pores, which communicate with a longitudinal tube. By chemical analysis, wool gives a great deal of oil, and carbonate of ammonia; caustic alkaline leys dissolve it entirely. It experiences no change in boiling water; it alters very little when preserved in a place well aired; acids have very little action on it; when exposed to a strong heat, it enters into fusion.

An examination of these chemical facts is necessary for understanding the principles which ought to direct the artist in the bleaching of this substance. The little action which acids have upon wool, and its unalterableness in water, even when aided by heat, render it necessary to have recourse to alkaline or saponaceous leys; but its solubility in

these salts shews, that great prudence and caution must be employed. In regard to acids, none have been hitherto used but the sulphureous acid, obtained in the gaseous state by combustion.

In the preliminary operations to which wool is subjected, it is customary to leave a little of its grease, to secure it from insects. Wool is often freed from the grease by the farmers, when they wish to sell it at a high price, but in the subsequent manipulations, it is greased or oiled before it is combed, spun, &c. and as this fat matter attracts dust, it dirties and thickens the stuffs. The first kind of bleaching to which wool is subjected, is to free it from these impurities. This operation is called scouring. In manufactories, it is generally performed by means of an ammoniacal ley, formed of five measures of river water, and one of stale urine; the wool is immersed for about twenty minutes in a bath of this mixture, heated to fifty-six degrees; it is then taken out, suffered to drain, and then rinsed in running water: this manipulation softens the wool, and gives it the first degree of whiteness; it is repeated a second, and even a third time, after which the wool is fit to be employed. In some places, scouring is performed with water slightly impregnated with soap; and indeed, for valuable articles, this process is preferable, but it is too expensive for articles of less value.

Fulling the cloth adds still to the whiteness; and if an increased degree be necessary, it may be procured by the action of the sulphureous acid; that is to say, of the fumes of sulphur in a state of combustion, or the vapour of that acid condensed and combined with water.

Sulphuring is generally performed in an arched or very close chamber, constructed in such a manner, that the articles to be exposed to the action of the sulphur can be suspended on poles. The chamber being filled, a certain quantity of sulphur is put in a state of combustion in flat dishes, having a large surface with very little depth; the entrance is speedily shut, and all the interstices around the door are carefully stopped to prevent the access of the atmospheric air. The acid generated by the combustion of the sulphur, penetrates the stuffs, attacks the colouring matter, destroys it, and effects the bleaching. The stuffs are left in the stoves some time after the deflagration has ceased. This time varies from six to twenty-four hours. They are then taken out, and made to pass through a slight washing with soap, to remove the roughness they have acquired by the action of the acid, and to give them the necessary softness.

This process is imperfect. At first, the acid of the sulphur acts only on the surfaces, and does not penetrate. This aerial immersion is not sufficient; the gas cannot introduce itself to a sufficient depth into the stuffs, and the superficies only is whitened.

A superior method has been lately invented, which is by making use of the sulphureous acid, which has been already described.

The sulphureous acid, or that acid generated by the imperfect combustion of sulphur, differs from the sulphuric acid (oil of vitriol), by its containing less of the acidifying principle, and by being, as we may say, the mean term between sulphur and the sulphuric acid.

Sulphureous acid gas unites very easily with water, and in this combination it may be employed for bleaching wool and silk. The sulphureous acid in this state of liquidity, may be prepared by making it traverse water in an apparatus nearly similar to that used for preparing oxygenated muriatic acid. The most economical method of obtaining

it, is to decompose sulphuric acid by the mixture of any combustible matter capable of taking from it a part of its oxygen. In exact experiments of the laboratory, when the chemist is desirous of having great purity, it is obtained by means of metallic substances, and particularly by mercury; but for the purpose of which we are treating, where great economy is required, we would recommend the most common substances. We shall therefore give the following process.

Take chopped straw, or saw-dust, and introduce it into a mattress; pour over it sulphuric acid, applying at the same time heat, and there will be disengaged sulphureous acid gas (vapour of sulphur), which may be combined with water in the apparatus.

The pieces are rolled upon the reels, and are drawn through the sulphureous acid, by turning them, until it is observed that the whiteness is sufficiently bright. They are then taken out, and are left to drain on a bench covered with cloth, lest they should be stained in consequence of the decomposition of the wood by the sulphureous acid; they are next washed in river water, and Spanish white is employed, if it should be judged necessary. This operation is performed by passing the pieces through a tub of clear water, in which about eight pounds Spanish white have been dissolved. To obtain a fine whiteness, the stuffs, in general, are twice sulphured. According to this process, one immersion and reeling two or three hours, is sufficient. Azuring or blueing is performed by throwing into the Spanish white liquor, a solution of one part of Prussian blue to 400 parts of water, shaking the cloth in the liquid, and reeling it rapidly.

The operation is terminated by a slight washing with soap, to give softness and pliability to the stuffs. The final operations of drying, stretching, pressing, &c. are foreign to our present subject.

Bleaching of Silk.—Silk is a semi-transparent matter, spun by a caterpillar, and formed of a substance contained in its body, which becomes hard in the air. This insect inhabits warm climates, being indigenous in Asia: it was naturalized in Europe about the time of the downfal of the Roman empire.

The filaments prepared by the silk-worm are rolled up in a cod or ball. In this state, in which we find it, it is covered with a yellow varnish which destroys its brilliancy and renders it rough. Silk by chemical analysis gives carbonate of ammonia and oil; water at a boiling heat produces no effect upon it; alcohol makes it experience no change; but concentrated alkaline leys attack and dissolve it.

To give splendour to silk, it must be freed from its varnish. This covering is soluble in alkaline leys. Silk is generally scoured by means of soap, by which it loses one-fourth of its weight. The matter disengaged from it is very fœtid, and if the silk be not rinsed in plenty of water, putrid fermentation will take place. Even when the best soap is used, it is generally suspected that it injures the whiteness of the silk. The splendour of the Chinese silks is brighter than that of the European; and the Chinese employ no soap in their operations. A slightly alkaline ley will dissolve the varnish of the silk without using soap, and this has also been effected by the action of boiling water at a very high temperature.

The method which has been used successfully in France, is as follows:

Take a very weak solution of caustic soda, and fill with it the boiler of the apparatus for bleaching with steam. Charge the frames with

skeins of raw silk, and place them in the apparatus until it is full; then close the door and make the solution boil. Having continued the ebullition for twelve hours, slacken the fire, and open the door of the apparatus. The heat of the steam, which is always above 250°, will have been sufficient to free the silk from the gum, and to scour it. Wash the skeins in warm water, and, having wrung them, place them again on the frames in the apparatus, to undergo a second boiling. Then wash them several times in water, and immerse them in water somewhat soapy, to give them a little softness.

Notwithstanding the whiteness which silk acquires by these different operations, it must be carried to a higher degree of splendour by exposing it to the action of sulphureous acid gas, in a close chamber, or by immersing it in sulphureous acid, as before recommended for wool.

Bleaching Prints, and Printed Books.—An application has been made of the new mode of bleaching, to the whitening of books and prints that have been soiled by smoke and time.

Simple immersion in oxygenated muriatic acid, letting the article remain in it a longer or shorter space of time, according to the strength of the liquid, will be sufficient to whiten an engraving. If it be required to whiten the paper of a bound book, as it is necessary that all the leaves should be moistened by the acid, care must be taken to open the book well, and to make the boards rest on the edge of the vessel, in such a manner that the paper alone be dipped in the liquid: the leaves must be separated from each other, in order that they may be equally moistened on both sides.

The liquor assumes a yellow tint, and the paper becomes white in the same proportion; at the end of two or three hours, the book may be taken from the acid liquor, and plunged into pure water, with the same care and precaution as recommended in regard to the acid liquor, that the water may exactly touch the two surfaces of each leaf. The water must be renewed every hour, to extract the acid remaining in the paper, and to dissipate the disagreeable smell.

By following this process, there is some danger that the pages will not be all equally whitened, either because the leaves have not been sufficiently separated, or because the liquid has had more action on the front margins than on those near the binding. On this account, the best way is to destroy the binding entirely, that each leaf may receive an equal and perfect immersion; and this is the second process recommended by M. Chaptal.

"They begin," says he, "by unsewing the book, and separating it into leaves, which they place in cases formed in a leaden tub, with very thin slips of wood, or glass, so that the leaves, when laid flat, are separated from each other by intervals scarcely sensible. The acid is then poured in, making it fall on the sides of the tub, in order that the leaves may not be deranged by its motion. When the workman judges, by the whiteness of the paper, that it has been sufficiently acted upon by the acid, it is drawn off by a cock at the bottom of the tub, and its place is supplied by clear fresh water, which weakens and carries off the remains of the acid, as well as the strong smell. The leaves are then to be dried, and after being pressed, may be again bound up.

"The leaves may be placed also vertically in the tub; and this position seems to possess some advantage, as they will be less liable to be

torn. With this view I constructed a wooden frame, which I adjusted to the proper height, according to the size of the leaves which I wished to whiten. This frame supported very thin slips of wood, leaving only the space of half a line between them. I placed two leaves in each of these intervals, and kept them fixed in their place by two small wooden wedges, which I pushed in between the slips. When the paper was whitened, I lifted up the frame with leaves, and plunged them in cold water, to remove the remains of the acid as well as the smell: this process I prefer to the other.

"By this operation books are not only cleaned, but the paper acquires a degree of whiteness superior to what it possessed when first made. The use of this acid is attended also with the valuable advantage of destroying ink spots. This liquor has no action upon spots of oil or animal greese; but it has been long known that a weak solution of potass will effectually remove stains of that kind.

"When I had to repair prints so torn that they exhibited only scraps pasted upon other paper, I was afraid of losing these fragments in the liquid, because the paste became dissolved. In such cases I inclosed the prints in a cylindric glass vessel, which I inverted on the water in which I had put the mixture proper for extricating the oxygenated muriatic acid gas. This vapour, by filling the whole inside of the jar, acted upon the print, extracted the grease as well as ink spots, and the fragments remained pasted to the paper."

Easy Method of preparing the Oxygenated Muriatic Acid.—To oxygenate the muriatic acid, nothing is necessary but to dilute it, and mix it in a very strong glass vessel with manganese, in such a manner that the mixture may not occupy the whole contents of the glass. Air bubbles are formed on the surface of the liquor; the empty space becomes filled with a greenish vapour; and at the end of some hours the acid may be farther diluted with water, and then used. It has an acid taste, because the whole is not saturated with oxygen; but it possesses all the virtues of the oxygenated muriatic acid. This process may be followed when there is not time to set up an apparatus for distilling, in order to procure the oxygenated acid.

Method of bleaching Straw.—Dip the straw in a solution of oxygenated muriatic acid, saturated with potass. (Oxygenated muriate of lime is much cheaper.) The straw is thus rendered very white, and its flexibility is increased.

Efficacy of Horse Chesnuts in bleaching Linen and clearing Woollen Stuffs, and a Ley for preparing Hemp.—The manner of making this ley is to peel the chesnuts, and rasp them as fine as possible into soft water. This is done ten or twelve hours before the mixture is to be used; and in the meanwhile, it is stirred from time to time, the better to dissolve these raspings and impregnate the water. The last stirring is given about a quarter of an hour before the water is drawn off from the thickest part of the raspings, which subside; and this is done either by inclining the vessel and pouring off the ley gently, or by ladling it out by hand, while the water is yet white and froths like soap-suds. In order to use this ley, it is made rather hotter than the hand can well bear, and the hemp is then steeped and washed in it as in soap-suds. Linen may also be washed in this ley, and even when very dirty, much less soap will be required than is commonly used, it being sufficient to rub the dirtiest parts only with soap.—The raspings

of the chesnuts, which sink to the bottom of the ley, are good for fowls and pigs. Hemp, as above prepared, may be dyed like silk, wool, or cotton, and may be made into stuff and garments of all kinds; a great advantage attending the use of this material is, that it will not be destroyed by those insects which devour woollen cloth.

To bleach Bees-Wax.—Melt your wax, and while hot throw it into cold water to reduce it into little bits, or spread it out into very thin leaves, and lay it out to the air, night and day, on linen cloths, then melt it over again, and expose it as before: repeat this till the sun and dew have bleached it; then, for the last time, melt it in a kettle, and cast it with a ladle on a table covered over with little round hollows, in the form of the cakes sold by the apothecaries; but first wet your moulds with cold water, that the wax be the easier got out; lastly, lay them out in the air for two days and two nights, to make it more transparent and drier.

CHAP. XVII.

INK-MAKING.

Inks are fluid compounds, intended to form characters, or some other kinds of figures, on proper grounds of paper, parchment, or such other substance as may be fit to receive them.

There are two principal kinds of inks—writing and printing ink.

Writing Ink.—When to an infusion of nut-galls some solution of sulphate of iron (green copperas) is added, a very dark blue precipitate takes place. This precipitate is the gallic acid of the galls united to the iron of the green vitriol, forming gallat of iron, which is the basis of writing ink. If galls and sulphate of iron only were used, the precipitate would fall down, leaving the water colourless; and, in order to keep it suspended in the water, forming a permanently black, or rather very dark blue fluid, gum-arabic is added, which, by its viscid nature, prevents the precipitate from falling down.

Various receipts have been given for the composition of writing ink, but very few have been founded upon a knowledge of it real nature. Though so important an article, it is but lately that it has been studied with any attention; and even still the principles and theory of its formation do not appear to be so thoroughly understood as might be wished. The receipt given by M. Ribancourt is as follows: Take eight ounces of Aleppo galls, in coarse powder; four ounces of logwood, in thin chips; four ounces of sulphate of iron (green copperas); three ounces of gum-arabic, in powder; one ounce of sulphate of copper (blue vitriol); and one ounce of sugar-candy. Boil the galls and logwood together in twelve pounds of water for one hour, or till half the liquid has been evaporated. Strain the decoction through a hair sieve, or linen cloth, and then add the other ingredients. Stir the mixture till the whole is dissolved, more especially the gum; after which, leave it to subside for twenty-four hours. Then decant the ink, and preserve it in bottles of glass or stone-ware well corked.

Another Receipt to make One Gallon of Black Writing Ink.—Into a glazed stone jar or pitcher put one pound of Aleppo galls, slightly bruised; then add one gallon of rain water, nearly of a boiling heat; let these stand together for fourteen days upon the kitchen hearth, or moderately warm; after that time add four ounces of green copperas or sulphate of iron, four ounces of logwood chips or shavings, one ounce of alum, one ounce of sugar-candy, and four ounce of gum-arabic or senegal. Let the whole remain ten or twelve days longer in a moderate heat, the mouth of the vessel slightly covered with paper. Stir the ingredients well with a stick twice a day during the whole time; then strain off the ink through linen or flannel, bottle it, pour a little brandy on the top of the ink in each bottle, then cork them well, and keep them for use in a place of temperate heat.

This ink may be depended upon as excellent, durable, and preserving the writing all a deep black.

N.B. The best galls for the purpose are those which are dark coloured, heavy, and free from grub holes.

Red Writing Ink is made in the following manner: Take of the raspings of Brazil-wood a quarter of a pound, and infuse them two or three days in vinegar. Boil the infusion for an hour over a gentle fire, and afterwards filtre it while hot. Put it again over the fire, and dissolve in it, first, half an ounce of gum-arabic, and afterwards of alum and white sugar each half an ounce.

Another Method to make Red Ink.—Take a quarter of a pound of the best Brazil-wood (get it in the log if possible, and rasp or shave it yourself), one ounce of cream of tartar, and one ounce of alum; boil these ingredients in a quart of clear water till half is consumed, then add to the ink, when filtered hot, one ounce of gum-arabic and one ounce of fine sugar.

A little salt added will prevent it from becoming mouldy.

To prevent Ink from moulding.—Half a dozen cloves, bruised with gum-arabic, are to be put into the bottle. If a very fine ink is wanted, white wine, or vinegar and water, should be used instead of water alone.

To make Indian Ink.—Put six lighted wicks into a dish of oil; hang an iron or tin concave cover over it so as to receive all the smoke; when there is a sufficient quantity of soot settled to the cover, then take it off gently with a feather upon a sheet of paper, and mix it up with gum-tragacanth to a proper consistence.

N.B. The clearest oil makes the finest soot, consequently the best ink.

To make China Ink.—Take dried black horse beans, burn them to a powder, mix them up with gum-arabic water, and bring them to a mass; press it well, and let it dry.

Substitute for Indian Ink.—Boil parchment slips, or cuttings of glove leather, in water, till it forms a size, which, when cool, becomes of the consistence of jelly; then having blackened an earthen plate, by holding it over the flame of a candle, mix up, with a camel-hair pencil, the fine lamp-black thus obtained, with some of the above size, while the plate is still warm. This black requires no grinding, and produces an ink of the very best colour, which works as freely with the pencil, and is as perfectly transparent as the best Indian ink; it possesses the advantage of furnishing artists with a substitute for that

article, which may be prepared in situations where it might be difficult to obtain the ink itself.

German Black for Printers.—Take the lees of port wine, dry and burn them; add thereto good ivory-black, the stones of cherries, plums, or other stone fruit, burnt in close vessels, and fine soft charcoal made from burnt willow; grind the whole well together into one mass, from which the best printing ink may be formed.

Permanent Writing Ink.—As common writing ink is susceptible of being effaced by oxygenated muriatic acid, and as the knowledge of this fact may be abused to very fraudulent purposes, the following composition for inks, absolutely indestructible, is recommended to the notice of the curious:

Boil one ounce of Brazil-wood, and three ounces of nut-galls, in forty-six ounces of water, till they shall be reduced to thirty ounces in all. Pour this decoction, while it is yet hot, upon half an ounce of sulphate of iron, or martial vitriol, a quarter of an ounce of gum-arabic, and a quarter of an ounce of white sugar. After these substances are dissolved, add to the solution one ounce and a quarter of indigo, finely pulverized, with three quarters of an ounce of lamp-black, very pure, of smoke black, previously diluted in one ounce of the best brandy.

The following receipt is still more simple: Boil one ounce of Brazil-wood with twelve ounces of water, and half an ounce of alum; continue the ebullition till the liquid mixture shall have been reduced to eight ounces; then add an ounce of the black oxyde of manganese, which has been reduced by decantation to extreme fineness, and, in mixture with it, half an ounce of gum-arabic.

Remark.—The chief advantage of this ink (said to be proposed by Schever) is, that it is in part a printer's ink: the black oxyde of manganese and the lamp-black not being affected by acids, and the indigo in powder but slightly, so that they must be effaced by rubbing or washing off, and not by solution. The ink, however, is not absolutely indestructible, nor equal to the common indelible ink, which may be used on paper as well as silk, linen, and cotton cloths.

Permanent Red Ink for marking Linen.—This useful preparation, which was contrived by the late learned and ingenious Dr. Smellie of Edinburgh, who was originally a printer in that city, may be used either with types, a hair pencil, or even with a pen. Take half an ounce of vermilion, and a dram of salt of steel; let them be finely levigated with linseed-oil to the thickness or limpidity required for the occasion. This has not only a very good appearance; but will, it is said, be found perfectly to resist the effects of acids, as well as of all alkaline leys. It may be made of other colours, by substituting the proper articles instead of vermilion.

Sympathetic Inks.—Sympathetic inks are such as do not appear after they are written with, but which may be made to appear at pleasure. A variety of substances have been used for this purpose. We shall describe the best of them.

1. Dissolve some sugar of lead in water, and write with the solution. When dry no writing will be visible. When you want to make it appear, wet the paper with a solution of alkaline sulphuret (liver of sulphur), and the letters will immediately appear of a brown colour. Even exposing the writing to the vapours of these solutions will render it apparent.

2. Write with a solution of gold in aqua-regia, and let the paper dry gently in the shade. Nothing will appear; but draw a sponge over it wetted with a solution of tin in aqua-regia; the writing will immediately appear of a purple colour.

3. Write with an infusion of galls; and when you wish the writing to appear, dip it into a solution of green vitriol; the letters will appear black.

4. Write with diluted sulphuric acid, and nothing will be visible. To render it so, hold it to the fire, and the letters will instantly appear black.

5. Juice of lemons or onions, a solution of sal ammoniac, green vitriol, &c. will answer the same purpose, though not so easily or with so little heat.

6. Green sympathetic ink. Dissolve cobalt in nitro-muriatic acid, and write with the solution. The letters will be invisible till held to the fire, when they will appear green, and will disappear completely again when removed into the cold. In this manner they may be made to appear and disappear at pleasure.

A very pleasant experiment of this kind, is to make a drawing representing a winter scene, in which the trees appear void of leaves, and to put the leaves on with this sympathetic ink; then, upon holding the drawing near to the fire, the leaves will begin to appear in all the verdure of spring, and will very much surprise those who are not in the secret.

7. Blue sympathetic ink. Dissolve cobalt in nitric acid; precipitate the cobalt by potass; dissolve this precipitated oxyde of cobalt in acetic acid, and add to the solution one-eighth of common salt. This will form a sympathetic ink, that, when cold, will be invisible, but will appear blue by heat.

CHAP. XVIII.

REMOVING STAINS.

The stains of ink on cloth, paper, or wood, may be removed by almost all acids, but those acids are to be preferred which are least likely to injure the texture of the stained substance. The muriatic acid, diluted with five or six times its weight of water, may be applied to the spot, and after a minute or two may be washed off, repeating the application as often as may be found necessary. But the vegetable acids are attended with less risk, and are equally effectual. A solution of the oxalic, citric (acid of lemons), or tartareous acids in water, may be applied to the most delicate fabrics without any danger of injuring them; and the same solutions will discharge writing, but not printing ink. Hence they may be employed in cleaning books which have been defaced by writing on the margin, without impairing the text. Lemon juice, and the juice of sorrels, will also remove ink stains, but not so easily as the concrete acid of lemons or citric acid.

To remove Iron Stains.—These may be occasioned either by ink

stains, which, on the application of the soap, are changed into iron stains, or by the direct contact of rusted iron. They may be removed by diluted muriatic acid, or by one of the vegetable acids already mentioned. When suffered to remain long on cloth, they become extremely difficult to take out, because the iron, by repeated moistening with water, and exposure to the air, acquires such an addition of oxygen, as renders it insoluble in acids. It has been found, however, that even these spots may be discharged, by applying first a solution of an alkaline sulphuret, which must be well washed from the cloth, and afterwards a liquid acid. The sulphuret, in this case, extracts part of the oxygen from the iron, and renders it soluble in diluted acids.

To remove the Stains of Fruit and Wine.—These are best removed by a watery solution of the oxygenated muriatic acid, or by that of oxygenated muriate of potass or lime, to which a little sulphuric acid has been added. The stained spot may be steeped in one of these solutions till it is discharged; but the solution can only be applied with safety to white goods, because the uncombined oxygenated acid discharges all printed and dyed colours. A convenient mode of applying the oxygenated acid, easily practicable by persons who have not the apparatus for saturating water with the gas, is as follows: Put about a table-spoonful of muriatic acid (spirit of salt) into a tea-cup, and add to it about a tea-spoonful of powdered manganese; then set this cup in a larger one filled with hot water; moisten the stained spot with water, and expose it to the fumes that arise from the tea-cup. If the exposure be continued a sufficient length of time, the stain will disappear.

To remove Spots of Grease from Cloth.—Spots of grease may be removed by a diluted solution of potass, but this must be cautiously applied, to prevent injury to the cloth. Stains of white wax, which sometimes fall upon the clothes from wax candles, are removable by spirits of turpentine, or sulphuric ether. The marks of white paint may also be discharged by the last mentioned agents.

To take Spots of Grease out of Books, Prints, or Paper.—After having gently warmed the paper that is stained with grease, wax, oil, or any other fat body, take out as much as possible of it by means of blotting paper; then dip a small brush in the essential oil of turpentine, heated almost to ebullition (for when cold it acts only very weakly), and draw it gently over both sides of the paper, which must be carefully kept warm. This operation must be repeated as many times as the quantity of the fat body imbibed by the paper, or the thickness of the paper, may render necessary. When the greasy substance is entirely removed, recourse may be had to the following method to restore the paper to its former whiteness, which is not completely restored by the first process. Dip another brush in highly rectified spirit of wine, and draw it in like manner over the place which was stained, and particularly round the edges, to remove the border that would still present a stain. By employing these means with proper caution, the spot will totally disappear, the paper will resume its original whiteness, and if the process has been employed on a part written on with common ink, or printed with printer's ink, it will experience no alteration.

To make portable Balls, for removing Spots from Clothes in general.—Take fullers'-earth, perfectly dried, so that it crumbles into a powder; moisten it with the clear juice of lemons, and add a small quantity of pure pearl ashes; then work and knead the whole carefully together,

till it acquires the consistence of a thick elastic paste; form it into convenient small balls, and expose them to the heat of the sun, in which they ought to be completely dried. In this state they are fit for use in the manner following:—First, moisten the spot on your clothes with water, then rub it with the ball just described, and suffer it again to dry in the sun: after having washed the spot with pure water, it will entirely disappear.

The Fumes of Brimstone useful in removing Spots or Stains in Linen, &c.—If a red rose be held in the fumes of a brimstone-match, the colour will soon begin to change, and, at length, the flower will become white. By the same process, fruit-stains or iron-moulds may be removed from linen or cotton cloths, if the spots be previously moistened with water. With iron-moulds, weak muriatic acid is preferable, assisted by heat; as by laying the cloth on a tea-pot or kettle, filled with boiling water.

To remove Spots of Grease from Paper.—Take an equal quantity of roach alum, burnt, and flower of brimstone, finely powdered together; wet the paper a little, and put a small quantity of the powder on the place, rubbing it gently with your finger, and the spot will disappear.

Substitute for Salt of Sorrel, for removing Ink Spots and Iron-moulds.—Take six parts of crystals of tartar, in powder, three parts of alum, likewise pulverized, and use them in the same manner as salt of sorrel.

Expeditious Method of taking out Stains from Scarlet, or Velvet of any other Colour.—Take soap wort, bruise it, strain out its juices, and add to it a small quantity of black soap. Wash the stain with this liquor, suffering it to dry between whiles, and by this method the spots will in a day or two entirely disappear.

To take Spots effectually out of Silk, Linen, or Woollen.—Spirits of turpentine, twelve drops, and the same quantity of spirits of wine; grind these with an ounce of pipe-maker's clay, and rub the spots therewith. You are to wet the composition when you do either silk, linen, or woollen with it; let it remain till dry, then rub it off, and the spot or spots will disappear.

True spirits of salts, diluted with water, will remove iron-moulds from linen; and sal-ammoniac, with lime, will take out the stains of wine.

To take the Stains of Grease from Woollen or Silk.—Three ounces of spirits of wine, three ounces of French chalk, powdered, and five ounces of pipe-clay. Mix the above ingredients, and make them up in rolls about the length of a finger, and you will find a never-failing remedy for removing grease from woollen or silken goods.

N. B. It is to be applied by rubbing on the spot either dry or wet, and afterwards brushing the place.

Easy and safe Method of discharging Grease Spots from Woollen Cloths.—Fullers'-earth, or tobacco-pipe clay, being put wet on an oil spot, absorbs the oil as the water evaporates, and leaves the vegetable or animal fibres of cloth clean, on being beaten or brushed out. When the spot is occasioned by tallow or wax, it is necessary to heat the part cautiously by an iron or the fire, while the cloth is drying. In some kinds of goods, blotting paper, bran, or raw starch, may be used with advantage.

To take out Spots of Ink.—As soon as the accident happens, wet the

place with juice of sorrel or lemon, or with vinegar, and the best hard white soap.

To take Iron-moulds out of Linen.—Hold the iron-mould on the cover of a tankard of boiling water, and rub on the spot a little juice of sorrel and a little salt, and when the cloth has thoroughly imbibed the juice, wash it in ley.

To take out Spots on Silk.—Rub the spots with spirit of turpentine; this spirit exhaling, carries off with it the oil that causes the spot.

To take Wax out of velvet of all Colours, except Crimson.—Take a crumby wheaten loaf, cut it in two, toast it before the fire, and, while very hot, apply it to the part spotted with wax. Then apply another piece of toasted bread hot as before, and continue this application till the wax is entirely taken out.

Process for preparing nitrous Acid for extracting Stains, &c. from tanned Leather.—Take half a pint of water, a quarter of a pint of nitrous acid, and half an ounce of salts of lemon. Put the water in a bottle, and add the nitrous acid to it, and afterwards the salts of lemon; when the heat which is caused by this mixture has subsided, add half a pint of skimmed milk; shake them occasionally for three or four days, and the liquor will be fit for use.

The application.—With a brush and soft water clean the surface of the leather from all grease, dirt, &c. Next scrape on it a little Bath brick, or white free sand; add a little of the above liquor, and with a brush scour it well, repeating this process till the whole has been gone over; then, with a clean sponge and water, wash off what remains of the brick: leave the leather to dry gradually, and it will be of a light new colour. If it is wished to be darker, brush it with a hard brush a little before it is dry, and it will be of a rich brown tinge.

To extract Grease Spots from Paper.—Scrape finely some pipe-clay, the quantity of which may be easily determined on making the experiment: lay thereon the sheet or leaf, and cover the spot in like manner with the clay; cover the whole with a sheet of paper; then apply, for a few seconds, a heated ironing box, or any substitute adopted by laundresses. On using Indian rubber to remove the dust taken up by the grease, the paper will be found restored to its original degree of whiteness and opacity.

To remove Spots of Grease from Books and Prints.—After having gently warmed the paper stained with grease, wax, oil, or any fat body whatever, take out as much as possible of it, by means of blotting paper. Then dip a small brush in the essential oil of well-rectified spirit of turpentine, heated almost to an ebullition (for when cold it acts only very weakly), and draw it gently over both sides of the paper, which must be carefully kept warm. This operation must be repeated as many times as the quantity of the fat body imbibed by the paper, or the thickness of the paper, may render necessary. When the greasy substance is entirely removed, recourse may be had to the following method to restore the paper to its former whiteness, which is not completely restored by the first process. Dip another brush in highly rectified spirit of wine, and draw it, in like manner, over the place which was stained, and particularly round the edges, to remove the border, that would still present a stain. By employing these means, with proper caution, the spot will totally disappear; the paper will resume its original whiteness; and if the process has been employed on a part writ-

ten on with common ink, or printed with printer's ink, it will experience no alteration.

To take Spots out of Cloths, Stuffs, Silk, Cotton, and Linen.---Take two quarts of spring water, put in it a little fine white potass, about the quantity of a walnut, and a lemon cut in slices; mix these well together, and let it stand for twenty-four hours in the sun; then strain it off, and put the clear liquid up for use. This water takes out all spots, whether pitch, grease, or oil, as well in hats, as cloths and stuffs, silk or cotton, and linen. As soon as the spot is taken out, wash the place with fair water; for cloths of a deep colour, add to a spoonful of the mixture as much fair water as to weaken it.

Grease spots in cloth may be removed by using soap and water with a tooth or nail brush, and afterwards wiping off the lather with the wet corner of a towel. Essence of lemon, or pure spirit of turpentine, will remove pitch from cloth, &c.

In woollen cloth, an easier method is to scrape off the hard tallow with the edge of a tea-spoon, then rub the part briskly with a clean woollen rag, shifting the rag as the part becomes dirty; or, place some blotting paper on the spot, press it with a hot iron, occasionally moving the paper.

Remedy against the Effects of Ink, when just spilled.—If the ink be spilled on a ruffle, or apron, &c. while you have it on, let one hold the spotted part between his two hands over a bason and rub it, while another pours water gradually from a decanter upon it, and let a whole pitcher-full be used if necessary; or if the ruffle, apron, &c. be at liberty, let it be dipped into a bason filled with water, and there squeezed and dipped in again, taking care to change the water in abundance every two or three squeezes. If the ink be spilled on a green table carpet, it may immediately be taken out with a tea-spoon so entirely, that scarcely any water at all shall be wanted afterwards, provided it was only that instant spilled, as the down of the cloth prevents the immediate soaking in of the ink, or of any other liquor (except oil); but if it have lain some time, be the time ever so long, provided the place be still wet, by pouring on it fresh clean water by little and little at a time, and gathering it up again each time with a spoon, pressing hard to squeeze it out of the cloth into the spoon, you will at last bring it to its natural colour, as if no such accident had happened.

CHAP. XIX.

STAINING WOOD.

To Stain Wood Yellow.---Take any white wood, and brush it over several times with the tincture of turmeric root, made by putting an ounce of turmeric, ground to powder, to a pint of spirit, and after they have stood for some days, straining off the tincture. If the yellow colour be desired to have a reddish cast, a little dragon's blood must be added.

A cheaper, but less strong and bright yellow, is by the tincture of French berries made boiling hot.

Wood may also be stained yellow by means of aquafortis, which will sometimes produce a very beautiful yellow colour, but at other times a browner. Care must be taken, however, that the aquafortis be not too strong, otherwise a blackish colour will be the result.

To stain Wood Red.—For a bright red stain for wood, make a strong infusion of Brazil-wood in stale urine, or water impregnated with pearl-ashes, in the proportion of an ounce to a gallon; to a gallon of either of which, the proportion of Brazil wood must be a pound, which being put to them, they must stand together for two or three days, often stirring the mixture. With this infusion strained, and made boiling hot, brush over the wood to be stained till it appear strongly coloured; then, while yet wet, brush it over with alum water made in the proportion of two ounces of alum to a quart of water.

For a less bright red, dissolve an ounce of dragon's blood in a pint of spirits of wine, and brush over the wood with the tincture till the stain appear to be as strong as is desired; but this is, in fact, rather lacquering than staining.

For a pink or rose red, add to a gallon of the above infusion of Brazil-wood two additional ounces of the pearl-ashes, and use it as was before directed: but it is necessary, in this case, to brush the wood over with the alum water. By increasing the proportion of pearl-ashes, the red may be rendered yet paler; but it is proper, when more than this quantity is added, to make the alum water stronger.

To stain Wood Blue.---Wood may be stained blue by means either of copper or indigo.

The method of staining blue with copper is as follows: Make a solution of copper in aquafortis, and brush it while hot several times over the wood; then make a solution of pearl-ashes in the proportion of two ounces to a pint of water, and brush it hot over the wood stained with the solution of copper, till it be of a perfectly blue colour.

To stain Wood Green.—Dissolve verdigrise in vinegar, or crystals of verdigrise in water, and with the hot solution brush over the wood till it be duly stained.

To stain Wood Purple.—Brush the wood to be stained several times with a strong decoction of logwood and Brazil, made in the proportion of one pound of the logwood, and a quarter of a pound of the Brazil, to a gallon of water, and boiled for an hour or more. When the wood has been brushed over till there be a sufficient body of colour, let it dry, and then be slightly passed over by a solution of one drachm of pearl-ashes in a quart of water. This solution must be carefully used, as it will gradually change the colour from a brown red, which it will be originally found to be, to a dark blue purple, and therefore its effect must be restrained to the due point for producing the colour desired.

To stain Wood a Mahogany Colour.—The substances used for staining mahogany colour are madder, Brazil-wood, and logwood; each of which produce reddish brown stains, and they must be mixed together in such proportions as will produce the tint required.

To stain Wood Black.—Brush the wood several times over with a hot decoction of logwood. Then having prepared an infusion of galls by putting a quarter of a pound of powdered galls to two quarts of water, and setting them in the sunshine, or any other gentle heat, for

three or four days, brush the wood over three or four times with it, and it will be of a beautiful black. It may be polished with a hard brush and shoemakers' black wax.

CHAP. XX.

PYROTECHNY,

OR THE ART OF PREPARING ALL KINDS OF FIRE WORKS.

Of Ingredients and Compositions.

Saltpetre being the principal ingredient in fire-works, and a volatile body by reason of its aqueous and aërial parts, is easily rarefied by fire, but not so soon when foul and gross as when purified from its crude and earthy parts, which greatly retard its velocity. When any quantity, therefore, of fire-works are to be made, it should be examined; for if it is not well cleansed, and of a good sort, your works will not have their proper effect; neither will the nitre agree with the required proportions. Therefore,

To refine Saltpetre.—Put in a copper or any other vessel, 100lb. of the rough salt, with 14 gallons of clean water, let it boil gently half an hour, and as it boils take off the scum: then stir it, and before it settles put it into your filtering bags, which must be hung on a rack, with glazed earthen pans under them, in which must be sticks laid across for the crystals to adhere to; it must stand in the pans two or three days to shoot; then take out the crystals, and let them dry. The water that remains in the pans boil again an hour, and strain it into the pans as before, and the saltpetre will be quite clear and transparent; if not, it wants more refining; to do which proceed as usual, till it is well cleansed of all its earthy parts. Those who do not choose to procure their saltpetre by the above method, may buy it ready made.

To pulverise Saltpetre.---Take a copper kettle, whose bottom must be spherical, and put into it 14lb. of refined saltpetre, with two quarts or five pints of clean water: then put the kettle on a slow fire; and when the saltpetre is dissolved, if any impurities arise, skim them off, and keep constantly stirring with two large spatulas, till all the water exhales; and, when done enough, it will appear like white sand, and as fine as flour; but, if it should boil too fast, take the kettle off the fire, and set it on some wet sand, which will prevent the nitre from sticking to the kettle. When you have pulverised a quantity of saltpetre, be careful to keep it in a dry place.

To extract Saltpetre from damaged Gunpowder.---Have some filtering bags hung on a rack, with glazed earthen pans under them, in the same manner as those for refining saltpetre; then take any quantity of damaged powder, and put it into a copper, with as much clean wa-

ter as will cover it: when it begins to boil, take off the scum; and, after it has boiled a few minutes, stir it up: then take it out of the copper with a small hand-kettle for that purpose, and put some into each bag, beginning at one end of the rack, so that by the time you have got to the last bag, the first will be ready for more. Continue thus till all the bags are full: then take the liquor out of the pans; which boil and filter as before, two or three times, till the water run quite clear, which you must let stand in the pan some time, and the saltpetre will appear at top. To get the saltpetre entirely out of the powder, take the water from that already extracted, to which add some fresh, and the dregs of the powder that remain in the bags, and put them in a vessel, to stand as long as you please: and, when you want to extract the nitre, you must proceed with this mixture as with the powder at first, by which means you will draw out all the saltpetre; but this process must be boiled longer than the first.

Sulphur, or Brimstone.—Sulphur is one of the principal ingredients in gunpowder, and almost in all compositions of fire-works; and therefore great care must be taken of its being good, and brougbt to the highest perfection. To know when sulphur is good, you are to observe that it is of a high yellow; and if, when held in one's hand, it crackles and bounces, it is a sign that it is fresh and good: but, as the method of reducing brimstone to a powder is very troublesome, it is better to buy the flour ready made, which is done in large quantities, and in great perfection; though when a grand collection of fire-works is to be made, the strongest and best sulphur is the lump brimstone ground in the manner directed farther on.

Charcoal.—Charcoal is a preservative by which the saltpetre and brimstone are made into gunpowder, by preventing the sulphur from suffocating the strong and windy exhalation of the nitre. Charcoal for fire-works must always be soft and well burnt, which may be bought ready done.

Gunpowder.—Take four ounces of refined saltpetre, an ounce of brimstone, and six drams of small-coal; reduce these to a fine powder, and continue beating them for some time in a stone mortar with a wooden pestle, wetting the mixture between whiles with water, so as to form the whole in an uniform paste, which is reduced to grains by passing it through a wire sieve fit for the purpose; and in this form being carefully dried, it becomes the common gunpowder. For making great quantities mills are built, by means of which more work may be done in one day than a man can do in a hundred.

Camphor.—This may be had in the shops; and is of two kinds, differing in regard to the degree of their purity, and distinguished by the name of rough and refined. Refined camphor must be chosen of a perfectly clean white colour, very bright and pellucid, of the same smell and taste with the rough, but more acrid and pungent. It is so volatile, that merchants usually inclose it in lintseed, that the viscosity of that grain may keep its particles together.

Benjamin.—This is a resin found of different sorts; and distinguished by their colours, viz. yellow, grey, and brown; but the best is that which is easy to break, and full of white spots. It is one of the ingredients in odoriferous fire-works, when reduced to a fine flour; which may be done by putting into a deep and narrow earthen pot 3 or 4 oz. of benjamin grossly pounded; cover the pot with paper, which tie very

close round the edge; then set the pot on a slow fire, and once in an hour take off the paper, and you will find some flour sticking to it, which return again into the pot; this you must continue till the flour appear white and fine. There is also an oil of benjamin, which is sometimes drawn from the dregs of the flour; it affords a very good scent, and may be used in wet compositions.

Spur Fire.—This fire is the most beautiful and curious of any yet known; and was invented by the Chinese, but now is in greater perfection in England than in China. As it requires great trouble to make it to perfection, it will be necessary that beginners should have full instructions; therefore care should be taken that all the ingredients are of the best; that the lamp-black is not damp and clodded, that the saltpetre and brimstone are thoroughly refined. This composition is generally rammed in 1 or 2 oz. cases about 5 or 6 inches long, but not driven very hard; and the cases must have their concave stroke struck very smooth, and the choak or vent not quite so large as the usual proportion; this charge, when driven and kept a few months, will be much better than when rammed; and will not spoil, if kept dry, in many years.

As the beauty of this composition cannot be seen at so great a distance as brilliant fire, it has a better effect in a room than in the open air, and may be fired in a chamber without any danger: it is of so innocent a nature, that, though with an improper phrase, it may be called a cold fire; and so extraordinary is the fire produced from this composition, that, if well made, the sparks will not burn a handkerchief when held in the midst of them. You may hold them in your hand while burning with as much safety as a candle; and if you put your hand within a foot of the mouth of the case, you will feel the sparks drop like drops of rain. When any of these spur-fires are fired singly, they are called *artificial flower-pots;* but some of them placed round a transparent pyramid of paper, and fired in a large room, make a very pretty appearance.

The composition consists of saltpetre 4 lb. 8 oz. sulphur 2 lb. and lamp-black 1 lb. 8 oz.; or saltpetre 1 lb. sulphur $\frac{1}{2}$ lb. and lamp-black 4 quarts. This composition is very difficult to mix. The saltpetre and brimstone must be first sifted together, and then put into a marble mortar, and the lamp-black with them, which you work down by degrees with a wooden pestle, till all the ingredients appear of one colour, which will be something greyish, but very near black: then drive a little into a case for trial, and fire it in a dark place; and if the sparks, which are called *stars* or *pinks,* come out in clusters, and afterwards spread well without any other sparks, it is a sign of its being good, otherwise not; for if any drossy sparks appear, and the stars not full, it is then not mixed enough; but if the pinks are very small, and soon break, it is a sign that you have rubbed it too much.

This mixture, when rubbed too much, will be too fierce, and hardly shew any stars; and, on the contrary, when not mixed enough, will be too weak, and throw out an obscure smoke, and lumps of dross, without any stars. The reason of this charge being called the spur-fire is, because the sparks it yields have a great resemblance to the rowel of a spur, from whence it takes its name.

To meal Gunpowder, Brimstone, and Charcoal.

There have been many methods used to grind these ingredients to a powder for fire-works, such as large mortars and pestles made of ebony and other hard wood, and horizontal mills with brass barrels; but none have proved so effectual and speedy as the last invention, that of the mealing-table, made of elm, with a rim round its edge four or five inches high; and at the narrow end is a slider that runs in a groove, and forms part of the rim: so that, when you have taken out of the table as much powder as you can with the copper shovel, sweep all clean out at the slider. When you are going to meal a quantity of powder, observe not to put too much in the table at once; but when you have put in a good proportion, take the muller and rub it till all the grains are broke; then searce it in a lawn sieve that has a receiver and top to it; and that which does not pass through the sieve, return again to the table, and grind it till you have brought it all fine enough to go through the sieve. Brimstone and charcoal are ground in the same manner, only the muller must be made of ebony; for these ingredients, being harder than powder, would stick in the grain of elm, and be difficult to grind. As brimstone is apt to stick and clod to the table, it will be best to keep one for that pursose, by which means you will always have your brimstone clean and well ground. These may be purchased at any of the turners' shops in London.

To make Wheels and other Works incombustible.

It being necessary, when your works are new, to paint them of some dark colour; therefore, if, instead of paint, you make use of the following composition, it will give them a good colour, and in a great measure prevent their taking fire so soon as if painted. Take brick-dust, coal-ashes, and iron-filings, of each an equal quantity, and mix them with a double size, made hot. With this wash over your works, and when dry wash them over again; this will preserve the wood greatly against fire. Let the brick-dust and ashes be beat to a fine powder.

To prepare Cast Iron for Gerbes, white Fountains, and Chinese Fire.

Cast-iron being of so hard a nature as not to be cut by a file, we are obliged to reduce it into grains, though somewhat difficult to perform; but, if we consider what beautiful sparks this sort of iron yields, no pains should be spared to granulate such an essential material; to do which, get at an iron-foundry some thin pieces of iron, such as generally run over the mould at the time of casting: then have a square block made of cast-iron, and an iron square hammer about four pounds weight; then, having covered the floor with cloth, or something to catch the beatings, lay the thin pieces of iron on the block, and beat them with the hammer till reduced into small grains; which afterwards searce with a very fine seive, to separate the fine dust, which is sometimes used in small cases of brilliant fire, instead of steel dust; and, when you have got out all the dust, sift what remains with a sieve a little larger, and so on with sieves of different sizes, till the iron passes through about the bigness of small bird-shot: your iron thus beat and sifted, put each sort into wooden boxes or oiled paper to keep it from rusting. When you use it, observe the difference of its size, in proportion to the cases for which the charge is intended; for the coarse sort is only designed for very large gerbes of 6 or 8lb.

Charges for Sky Rockets, &c.

Rockets of four ounces.—Meal powder 1 lb. 4 oz. saltpetre 4 oz. and charcoal 2 oz.

Rockets of eight ounces.—Method I. Meal powder 1 lb. saltpetre 4 oz. brimstone 3 oz. and charcoal $1\frac{1}{2}$ oz. Method II. Meal powder $1\frac{1}{2}$ lb. and charcoal $4\frac{1}{4}$ oz.

Rockets of one pound.—Meal powder 2 lb. saltpetre 8 oz. brimstone 4 oz. charcoal 2 oz. and steel-filings $4\frac{1}{2}$ oz.

Sky Rockets in general.—Method I. Saltpetre 1 lb. brimstone 1 lb. and charcoal $1\frac{1}{2}$ lb. II. Saltpetre 4 lb. brimstone $1\frac{1}{2}$ lb. charcoal 1 lb. 12 oz. and meal powder 2 oz.

Large Sky Rockets.—Saltpetre 4 lb. meal powder 1 lb. and brimstone 1 lb.

Rockets of a middling size.—Method I. Saltpetre 8 lb. sulphur 3 lb. meal powder 3 lb. II. Saltpetre 3 lb. sulphur 2 lb. meal powder 1 lb. charcoal 1 lb.

For Rocket Stars.

White Stars.—Meal powder 4 oz. saltpetre 12 oz. sulphur vivum 6 oz. oil of spike 2 oz. and camphor 5 oz.

Blue Stars.—Meal powder 8 oz. saltpetre 4, sulphur 2, spirit of wine 2, and oil of spike 2.

Coloured or variegated Stars.—Meal powder 8 drams, rochpetre 4 oz. sulphur vivum 2, and camphor 2.

Brilliant Stars.—Saltpetre $3\frac{1}{2}$ oz. sulphur $1\frac{1}{2}$, and meal powder $\frac{3}{4}$, worked up with spirits of wine only.

Common Stars.—Saltpetre 1 lb. brimstone 4 oz. antimony $4\frac{3}{4}$, isinglass $\frac{1}{2}$, camphor $\frac{1}{2}$, and spirits of wine $\frac{3}{4}$.

Tailed Stars, or Snakes.—Meal powder 3 oz. brimstone 2, saltpetre 1, and charcoal (coarsely ground) $\frac{3}{4}$.

Drove Stars.—Method I. Saltpetre 3 lb. sulphur 1 lb. brass dust 12 oz. antimony 3. II. Saltpetre 1 lb. antimony 4 oz. and sulphur 8.

Fixed pointed Stars.—Saltpetre $8\frac{1}{2}$ oz. sulphur 2, and antimony 1 oz. 10 drams.

Stars of a fine Colour.—Sulphur 1 oz. meal powder 1, saltpetre 1, camphor 4 dr. oil of turpentine 4 dr.

Rains.

Gold Rain for Sky Rockets.—Method I. Saltpetre 1 lb. meal powder 4 oz. sulphur 4, brass-dust 1, saw-dust $2\frac{1}{4}$, and glass-dust 6 dr. II. Meal powder 12 oz. saltpetre 2, charcoal 4. III. Saltpetre 8 oz. brimstone 2, glass-dust 1, antimony $\frac{3}{4}$, brass-dust $\frac{1}{4}$, and saw-dust 12 dr.

Silver Rain.—Method I. Saltpetre 4 oz. sulphur, meal powder, and antimony, of each 2 oz. sal prunella $\frac{1}{2}$ oz. II. Saltpetre $\frac{1}{2}$ lb. brimstone 2 oz. and charcoal 4. III. Saltpetre 1 lb. brimstone $\frac{1}{4}$ lb. antimony 6 oz. IV. Saltpetre 4 oz. brimstone 1, powder 2, and steel-dust $\frac{3}{4}$ oz.

Water Rockets.

Method I. Meal powder 6 lb. saltpetre 4, brimstone 3, charcoal 5. II. Saltpetre 1 lb. brimstone $4\frac{1}{2}$ oz. charcoal 6. III. Saltpetre 1 lb. brimstone 4 oz. charcoal 12. IV. Saltpetre 4 lb. brimstone $1\frac{1}{2}$ lb. charcoal 1 lb. 12 oz. V. Brimstone 2 lb. saltpetre 4 lb. and meal-powder 4. VI. Saltpetre 1 lb. meal powder 4 oz. brimstone $8\frac{1}{2}$, charcoal 2. VII. Meal powder 1 lb. saltpetre 3, brimstone 1, sea-coal 1 oz.

charcoal $8\frac{1}{2}$, saw-dust $\frac{3}{4}$, steel-dust $\frac{1}{2}$, and coarse charcoal $\frac{3}{4}$ oz. VIII. Meal powder $1\frac{3}{4}$ lb. saltpetre 3, sulphur $1\frac{1}{2}$, charcoal 12 oz. saw-dust 2.

Sinking Charges for Water Rockets.—Meal powder 8 oz. charcoal $\frac{3}{4}$ oz.

Of Wheels.

Wheel-cases, from two Ounces to four Pounds.—Method I. Meal powder 2 lb. saltpetre 4 oz. iron-filings 7. II. Meal powder 2 lb. saltpetre 12 oz. sulphur 4, steel-dust 3. III. Meal powder 4 lb. saltpetre 1 lb. brimstone 8 oz. charcoal $4\frac{1}{2}$ lb. IV. Meal powder 8 oz. saltpetre 4, saw-dust $1\frac{1}{2}$, sea-coal $\frac{3}{4}$. V. Meal powder 1 lb. 4 oz. brimstone 4 oz. 10 dr. saltpetre 8 oz. glass-dust $2\frac{1}{2}$. VI. Meal powder 12 oz. charcoal 1, saw-dust $\frac{1}{2}$. VII. Saltpetre 1 lb. 9 oz. brimstone 4 oz. charcoal $4\frac{1}{2}$. VIII. Meal powder 2 lb. saltpetre 1, brimstone $1\frac{1}{2}$, and sea-coal 2 oz. IX. Saltpetre 2 lb. brimstone 1, meal powder 4, and glass-dust 4 oz. X. Meal powder 1 lb. saltpetre 2 oz. and steel-dust $3\frac{1}{2}$. XI. Meal powder 2 lb. and steel-dust $2\frac{1}{2}$ oz. with $2\frac{1}{2}$ of the fine dust of beat iron. XII. Saltpetre 2 lb. 13 oz. brimstone 8 oz. and charcoal.

Slow Fire of Wheels.—Method I. Saltpetre 4 oz. brimstone 2, and meal powder $1\frac{1}{2}$. II. Saltpetre 4 oz. brimstone 1, and antimony 1 oz. 6 dr. III. Saltpetre $4\frac{1}{2}$ oz. brimstone 1 oz. and meal powder $1\frac{1}{2}$.

Dead Fire of Wheels.—Method I. Saltpetre $1\frac{1}{4}$ oz. brimstone $\frac{1}{4}$, lapis calaminaris $\frac{1}{4}$, and antimony 2 dr.

Standing on fixed Cases.

Method I. Meal powder 4 lb. saltpetre 2, brimstone and charcoal 1. II. Meal powder 2 lb. saltpetre 1, and steel-dust 8 oz. III. Meal powder 1 lb. 4 oz. and charcoal 4 oz. IV. Meal powder 1 lb. and steel-dust 4 oz. V. Meal powder $2\frac{1}{2}$ lb. brimstone 4 oz. and sea-coal 6. VI. Meal powder 3 lb. charcoal 5 oz. and saw-dust $1\frac{1}{2}$.

Sun Cases.

Method I. Meal powder $8\frac{1}{2}$ lb. saltpetre 1 lb. 2 oz. steel-dust 2 lb. 10 oz. brimstone 4. II. Meal powder 3 lb. saltpetre 6 oz. and steel-dust $7\frac{1}{2}$.

A brilliant Fire.

Meal powder 11 lb. saltpetre 1, brimstone 4 oz. steel-dust $1\frac{1}{2}$ lb.

Gerbes.

Meal powder 6 lb. and beat iron 2 lb. $1\frac{1}{4}$ oz.

Chinese Fire.

Saltpetre 12 oz. meal powder 2 lb. brimstone 1 lb. 2 oz. and beat iron 12 oz.

Tourbillons.

Charges for four-ounce Tourbillons.—Meal powder 2 lb. 4 oz. and charcoal $4\frac{1}{2}$ oz.

Eight-ounce Tourbillons.—Meal powder 2 lb. and charcoal $4\frac{3}{4}$ oz.

Large Tourbillons.—Meal powder 2 lb. saltpetre 1, brimstone 8 oz. and beat iron 8. Tourbillons may be made very large, and of different-coloured fires; only you are to observe, that the larger they are, the weaker must be the charge; and on the contrary, the smaller the stronger their charge.

Water Balloons.

Method I. Saltpetre 4 lb. brimstone 2, meal powder 2, antimony 4 oz. saw-dust 4, and glass-dust $1\frac{1}{4}$. II. Saltpetre 9 lb. brimstone 3 lb. meal powder 6 lb. rosin 12 oz. and antimony 8 oz.

Water Squibs.

Method I. Meal powder 1 lb. and charcoal 1 lb. II. Meal powder 1 lb. charcoal 9 oz.

Mine Ports or Serpents.

Method I. Meal powder 1 lb. and charcoal 1 lb. II. Meal powder 1 lb. charcoal 9 oz.

Port Fires.

For firing Rockets, &c.—Method I. Saltpetre 12 oz. brimstone 4 oz. and meal powder 2 oz. II. Saltpetre 8 oz. brimstone 4 oz. and meal powder 2 oz. III. Saltpetre 1 lb. 2 oz. meal powder $1\frac{1}{2}$ lb. and brimstone 10 oz. This composition must be moistened with 1 gill of linseed-oil. IV. Meal powder 6 oz. saltpetre 2 lb. 2 oz. and brimstone 10 oz. V. Saltpetre 1 lb. 4 oz. meal powder 4 oz. brimstone 5 oz. saw-dust 8 oz. VI. Saltpetre 8 oz. brimstone 2 oz. and meal powder 2 oz.

For Illuminations.—Saltpetre 1 lb. brimstone 8 oz. and meal powder 6 oz.

Cones or Spiral Wheels.

Saltpetre $1\frac{1}{2}$lb. brimstone 6 oz. meal powder 14 oz. and glass-dust 14 oz.

Crowns or Globes.

Saltpetre 6 oz. brimstone 2 lb. antimony 4 oz. and camphor 2 oz.

Air Balloon Fuzes.

Method I. Saltpetre 1 lb. 10 oz. brimstone 8 oz. and meal powder 1 lb. 6 oz. II. Saltpetre $1\frac{1}{2}$ lb. brimstone 8 oz. and meal powder 1 lb. 8 oz.

Serpents for Pots de Brins.

Meal powder 1 lb. 8 oz. saltpetre 12 oz. and charcoal 2 oz.

Fire Pumps.

Method I. Saltpetre 5 lb. brimstone 1 lb. meal powder $1\frac{1}{2}$ lb. and glass-dust 1 lb. II. Saltpetre 5 lb. 8 oz. brimstone 2 lb. meal powder 1 lb. 8 oz. and glass-dust 1 lb. 8 oz.

A slow White Flame.

Method I. Saltpetre 2 lb. brimstone 3 lb. antimony 1 lb. II. Saltpetre $3\frac{1}{2}$ lb. sulphur $2\frac{1}{2}$ lb. meal powder 1 lb. antimony $\frac{1}{2}$ lb. glass-dust 4 oz. brass-dust 1 oz. These compositions, driven $1\frac{1}{4}$ inch in a 1 oz. case, will burn one minute, which is a much longer time than an equal quantity of any composition yet known will last.

Amber Lights.

Meal powder 9 oz. amber 3 oz. This charge may be driven in small cases for illuminations.

Lights of another Kind.

Saltpetre 3 lb. brimstone 1 lb. meal powder 1 lb. antimony $10\frac{1}{2}$ oz. All these must be mixed with the oil of spike.

A Red Fire.

Meal powder 3 lb. charcoal 12 oz. and saw-dust 8 oz.

A common Fire.

Saltpetre 3 lb. charcoal 10 oz. and brimstone 2 oz.

To make an Artificial Earthquake.

Mix the following ingredients to a paste with water, and then bury it in the ground, and in a few hours the earth will break and open in several places. The composition—sulphur 4 lb. and steel-dust 4 lb.

Compositions for Stars of different Colours.

Method I. Meal powder 4 oz. saltpetre 2 oz. brimstone 2 oz. steel-dust 1½ oz. and camphor, white amber, antimony, and mercury sublimate, of each ½ oz. II. Rochpetre 10 oz. brimstone, charcoal, antimony, meal powder, and camphor, each ¾ oz. moistened with oil of turpentine. These powders are made into stars by being worked to a paste with aqua-vitæ, in which has been dissolved some gum-tragacanth; and after you have rolled them in powder, make a hole through the middle of each, and string them on quick-match, leaving about two inches between each. III. Saltpetre 8 oz. brimstone 2 oz. yellow amber 1 oz. antimony 1 oz. and powder 3 oz. VI. Brimstone 2½ oz. saltpetre 6 oz. olibanum or frankincense in drops 4 oz. mastic, and mercury sublimate, of each 4 oz. meal powder 5 oz. white amber, yellow amber, and camphor, of each 1 oz. antimony and orpiment ½ oz. each. V. Saltpetre 1 lb. brimstone ½ lb. and meal powder 8 oz. moistened with petrolio. VI. Powder ½ lb. brimstone and saltpetre of each 4 oz. VII. Saltpetre 4 oz. brimstone 2 oz. and meal powder 1 oz.

Stars that carry Tails of Sparks.—Method I. Brimstone 6 oz. antimony crude 2 oz. saltpetre 4 oz. rosin 4 oz. II. Saltpetre, rosin, and charcoal, of each 2 oz. brimstone 1 oz. and pitch 1 oz. These compositions are sometimes melted in an earthen pan, and mixed with chopped cotton-match, before they are rolled into stars; but will do as well if wetted, and worked up in the usual manner.

Stars that yield some Sparks.—Method I. Camphor 2 oz. saltpetre 1 oz. meal powder 1 oz. II. Saltpetre 1 oz. ditto melted ½ oz. and camphor 2 oz. When you would make stars of either of these compositions, you must wet them with gum-water, or spirits of wine, in which has been dissolved some gum-arabic, or gum-tragacanth, that the whole may have the consistence of a pretty thick liquid; having thus done, take 1 oz. of lint, and stir it about in the composition till it becomes dry enough to roll into stars.

Stars of a Yellowish Colour.—Take 4 oz. of gum tragacanth or gum-arabic, pounded and sifted through a sieve, camphor dissolved in brandy 2 oz. saltpetre 1 lb. sulphur ½ lb. coarse powder of glass 4 oz. white amber 1½ oz. orpiment 2 oz. Being well incorporated, make them into stars after the common method.

Stars of another Kind.—Take 1 lb. of camphor, and melt it in a pint of spirits of wine over a slow fire; then add to it 1 lb. of gum-arabic that has been dissolved; with this liquor mix 1 lb. of saltpetre, 6 oz. of sulphur, and 5 oz. of meal powder; and after you have stirred them well together, roll them into stars proportionable to the rockets for which you intend them.

Colours produced by the different Compositions.

As variety of fires adds greatly to a collection of works, it is necessary that every artist should know the different effect of each ingredient. For which reason we shall here explain the colours they produce of themselves; and likewise how to make them retain the same when mixed with other bodies: as for example, sulphur gives a blue, camphor a white or pale colour, saltpetre a clear white yellow, amber a colour inclining to yellow, sal-ammoniac a green, antimony a reddish, rosin a copper colour, and Greek pitch a kind of bronze, or between red and yellow. All these ingredients are such as shew themselves in flame, viz.

White Flame.—Saltpetre, sulphur, meal powder, and camphor; the saltpetre must be the chief part.

Blue Flame.—Meal powder, saltpetre, and sulphur vivum; sulphur must be the chief; or meal powder, saltpetre, brimstone spirit of wine, and oil of spike; but let the powder be the princial part.

Flame inclining to Red.—Saltpetre, sulphur, antimony, and Greek pitch; saltpetre the chief. By the above method may be made various colours of fire, as the practitioner pleases; for by making a few trials, he may cause any ingredient to be predominant in colour.

Ingredients that shew in Sparks when rammed in choaked Cases.

The set colours of fire produced by sparks are divided into four sorts, viz. the black, white, grey, and red. The black charges are composed of two ingredients, which are meal powder and charcoal; the white of thee, viz. saltpetre, sulphur, and charcoal; the grey of four, viz. meal powder, saltpetre, brimstone, and charcoal; and the red of three, viz. meal powder, charcoal, and saw-dust. There are, besides these four regular or set charges, two others, which are distinguished by the names of *compound* and *brilliant charges*, the compound being made of many ingredients, such as meal powder, saltpetre, brimstone, charcoal, saw-dust, sea-coal, antimony, glass-dust, brass-dust, steel-filings, cast-iron, tanners' dust, &c. or any thing that will yield sparks; all which must be managed with discretion. The brilliant fires are composed of meal powder, saltpetre, brimstone, and steel-dust; or with meal powder, and steel-filings only.

Cotton Quick-match

Is generally made of such cotton as is put in candles, of several sizes, from one to six threads thick, according to the pipe it is designed for; which pipe must be large enough for the match, when made, to be pushed in easily without breaking it. Having doubled the cotton into as many threads as you think proper, coil it very lightly into a flat-bottom copper or earthen-pan; then put in the saltpetre and the liquor, and boil them about twenty minutes; after which coil it again into another pan, and pour on it what liquor remains; then put in some meal powder, and press it down with your hands till it is quite wet; afterwards place the pan before a wooden frame, which must be suspended by a point in the centre of each end; and place yourself before the pan, tying the upper end of the cotton to the end of one of the sides of the frame. When every thing is ready, you must have one to turn the frame round, while you let the cotton pass through your hands, holding it very lightly, and at the same time keeping your hands full of the wet powder; but, if the powder should be too wet to stick to the cotton, put more in the pan, so as to keep a continual supply till the match is all wound up; you may wind it as close on the frame as you please, so that it do not stick together; when the frame is full, take it off the points, and sift dry meal powder on both sides of the match, till it appear quite dry: in winter the match will be a fortnight before it is fit for use; when it is thoroughly dry, cut it along the outside of one of the sides of the frame, and tie it up in skains for use: the match must be wound tight on the frames. The ingredients for the match are, cotton 1 lb. 12 oz. saltpetre 1 lb. spirits of wine 2 quarts, water 3 quarts, isinglass 3 gills, and meal powder 1 lb. To dissolve 4 oz. of isinglass, take 3 pints of water.

Touch-paper for capping of Serpents, Crackers &c.

Dissolve, in spirits of wine or vinegar, a little saltpetre; then take some purple or blue paper, and wet it with this liquor, and when dry it will be fit for use; when you paste this paper on any of your works, take care that the paste does not touch that part which is to burn. The method of using this paper is cutting it into slips, long enough to go once round the mouth of a serpent, cracker, &c. When you paste on these slips, leave a little above the mouth of the case not pasted; then prime the case with meal powder, and twist the paper to a point.

Of Moulds, Cases, Mixture, Instruments, &c.

Rocket Moulds.—As the performance of rockets depends much upon their moulds, it is requisite to give a definition of them and their proportions:—They are made and proportioned by the diameter of their orifice, which are divided into parts.

The rammers should have a collar of brass at the bottom, to keep the wood from spreading or splitting, and the same proportion must be given to all moulds from 1 oz. to 6 lb. The handles of the rammers should be equal to the bore of the mould, and 2 diameters long; but the shorter you can use them the better; for the longer the drift, the less will be the pressure on the composition by the blow given with the mallet.

Dimensions for Rocket Moulds, if the Rockets are rammed solid.

Weight of Rockets.	Length of Moulds without their Feet.	Interior Diameter of the Moulds.	Height of the Nipples.
lb. oz.	Inches.	Inches.	Inches.
6 0	34,7	3,5	1,5
4 0	38,6	2,9	1,4
2 0	13,35	2,1	1,0
1 0	12,25	1,7	0,85
0 8	10,125	1,333, &c.	0,6
0 4	7,75	1,125	0,5
0 2	6,2	0,9	0,45
0 1	4,9	0,7	0,35
0 ½	3,9	0,55	0,25
6 drams	3,5	0,5	0,225
4 drams	2,2	0,3	0,2

The diameter of the nipple must always be equal to that of the former. Those who make rockets for private amusement, should not ram them solid; for it requires a very skilful hand, and an expensive apparatus for boring them. Driving of rockets solid is the most expeditious method, but not so certain as ramming them over a piercer.

To roll Rockets and other Cases.—Sky-rocket cases are to be made 6½ of their exterior diameter long; and all other cases that are to be filled in moulds must be as long as the moulds, within half its interior diameter. Rocket cases, from the smallest to 4 or 6 lb. are generally made of the strongest sort of cartridge-paper, and rolled dry; but the large sort are made of pasted pasteboard. As it is very difficult to roll the ends of the cases quite even, the best way will be to keep a pattern of the paper for the different sorts of cases; which pattern should be somewhat longer than the case it is designed for, and on

it marked the number of sheets required, which will prevent any paper being cut to waste. Having cut your papers of a proper size, and the last sheet for each case with a slope at one end, so that when the cases are rolled it may form a spiral line round the outside, and that this slope may always be the same, let the pattern be so cut for a guide. Before you begin to roll, fold down one end of the first sheet so far that the fold will go two or three times round the former: then, on the double edge, lay the former with its handle off the table; and when you have rolled on the paper within two or three turns, lay the next sheet on that part which is loose, and roll it all on.

Having thus done, you must have a smooth board, about twenty inches long, and equal in breadth to the length of the case. In the middle of this board must be a handle placed lengthwise. Under this board lay your case, and let one end of the board lie on the table; then press hard on it, and push it forwards, which will roll the paper very tight: do this three or four times before you roll on any more paper. This must be repeated every other sheet of paper, till the case is thick enough; but if the rolling board be drawn backwards, it will loosen the paper: you are to observe, when you roll on the last sheet, that the point of the slope be placed at the small end of the roller. Having rolled your case to fit the mould, push in the small end of the former about 1 diameter from the end of the case, and put in the end-piece within a little distance of the former; then give the pinching chord one turn round the case, between the former and the end-piece; at first pull easy, and keep moving the case, which will make the neck smooth, and without large wrinkles. When the cases are hard to choak, let each sheet of paper (except the first and last, in that part where the neck is formed) be a little moistened with water. Immediately after you have struck the concave stroke, bind the neck of the case round with small twine, which must not be tied in a knot, but fastened with two or three hitches.

Having thus pinched and tied the case so as not to give way, put it into the mould without its foot, and with a mallet drive the former hard on the end-piece, which will force the neck close and smooth. This done, cut the case to its proper length, allowing from the neck to the edge of the mouth half a diameter, which is equal to the height of the nipple; then take out the former, and drive the case over the piercer with the long rammer, and the vent will be of a proper size. Wheel-cases must be drove on a nipple with a point to close the neck, and make the vent of the size required; which, in most cases, is generally $\frac{1}{4}$ of their interior diameter. As it is very often difficult, when the cases are rolled, to draw the roller out, you may make a hole through the handle, and put in it a small iron pin, by which you may easily turn the former round and pull it out.

Cases are commonly rolled wet, for wheels and fixed pieces; and when they are required to contain a great length of charge, the method of making those cases is thus: Your paper must be cut as usual, only the last sheet must not be cut with a slope: having your paper ready, paste each sheet on one side; then fold down the first sheet as before directed: but be careful that the paste do not touch the upper part of the fold; for, if the roller be wetted, it will tear the paper in drawing it out. In pasting the last sheet, observe not to wet the last turn or two in that part where it is to be pinched; for, if that part

be damp, the pinching cord will stick to it, and tear the paper; therefore, when you choak those cases, roll a bit of dry paper once round the case, before you put on the pinching cord; but this bit of paper must be taken off after the case is choaked. The rolling board, and all other methods, according to the former directions for the rolling and pinching of cases, must be used to these as well as all other cases.

To make Tourbillon Cases.---Those sort of cases are generally made about 8 diameters long; but if very large 7 will be sufficient: tourbillons will answer very well from 4 oz. to 2 lb. but when larger there is no certainty. The cases are best rolled wet with paste, and the last sheet must have a straight edge, so that the case may be all of a thickness: when you have rolled your cases after the manner of wheelcases, pinch them at one end quite close; then with the rammer drive the ends down flat, and afterwards ram in about $\frac{1}{3}$ of a diameter of dried clay. The diameter of the former for these cases must be the same as for sky-rockets. Tourbillons are to be rammed in moulds without a nipple, or in a mould without its foot.

Balloon Cases, or Paper Shells.---First you must have an oval former turned of smooth wood; then paste a quantity of brown or cartridge paper, and let it lie till the paste has quite soaked through; this done, rub the former with soap or grease, to prevent the paper from sticking to it; then lay the paper on in small slips, till you have made it $\frac{1}{2}$ of the thickness of the shell intended. Having thus done, set it to dry; and, when dry, cut it round the middle, and the two halves will easily come off: but observe, when you cut, to leave about 1 inch not cut, which will make the halves join much better than if quite separated. When you have some ready to join, place the halves even together, paste a slip of paper round the opening to hold them together, and let that dry; then lay on paper all over as before, everywhere equal, excepting that end which goes downwards in the mortar, which may be a little thicker than the rest; for that part which receives the blow from the powder in the chamber of the mortar consequently requires the greatest strength. When the shell is thoroughly dry, burn a round vent at top, with square iron, large enough for the fuze: this method will do for balloous from $4\frac{2}{5}$ inches to 8 inches diameter; but if they are larger, or required to be thrown a great height, let the first shell be turned of elm, instead of being made of paper.

For a balloon of $4\frac{2}{5}$ inches, let the former be 3 inches $\frac{1}{8}$ diameter, and $5\frac{1}{2}$ inches long. For a balloon of $5\frac{1}{2}$ inches, the diameter of the former must be 4 inches, and 8 inches long. For a balloon of 8 inches, let the diameter of the former be 5 inches and $\frac{10}{16}$, and $11\frac{7}{8}$ long. For a 10-inch balloon, let the former be $7\frac{3}{16}$ diameter, and $14\frac{1}{2}$ inches long. The thickness of a shell for a balloon of $4\frac{2}{5}$ inches must be $\frac{1}{2}$ inch. For a balloon of $5\frac{1}{8}$ inches, let the thickness of the paper be $\frac{5}{8}$ of an inch. For an 8-inch balloon, $\frac{7}{8}$ of an inch. And for a 10-inch balloon, let the shell be $1\frac{1}{8}$ inch thick.

Shells that are designed for stars only, may be made quite round, and the thinner they are at the opening, the better; for if they are too strong, the stars are apt to break at the bursting of the shell: when you are making the shell, make use of a pair of calibres, or a round gage, so that you may not lay the paper thicker in one place than another; and also to know when the shell is of a proper thickness. Balloons must always be made to go easy into the mortars.

Cases for illumination Port-fires.—These must be made very thin of paper, and rolled on formers, from $\frac{1}{4}$ to $\frac{5}{8}$ of an inch diameter, and from 2 to 6 inches long: they are pinched close at one end, and left open at the other. When you fill them, put in but a little composition at a time, and ram it in lightly, so as not to break the case: 3 or 4 rounds of paper, with the last round pasted, will be strong enough for these cases.

Cases and Moulds for common Port-fires.—Common port-fires are intended purposely to fire the works, their fire being very slow, and the heat of the flame so intense, that, if applied to rockets, leaders, &c. it will fire them immediately. Port-fires may be made of any length, but are seldom made more than 21 inches long: the interior diameter of port-fire moulds should be $\frac{10}{16}$ of an inch, and the diameter of the former $\frac{1}{2}$ an inch. The cases must be rolled wet with paste, and one end pinched, or folded down. The moulds should be made of brass, and to take in two pieces lengthwise; when the case is in the two sides, they are held together by brass rings, or hoops, which are made to fit over the outside. The bore of the mould must not be made quite through, so that there will be no occasion for a foot. Those port-fires, when used, are held in copper sockets, fixed on the end of a long stick: these sockets are made like port-crayons, only with a screw instead of a ring.

Of mixing the Compositions.—The performance of the principal part of fire-works depends much on the compositions being well mixed; therefore great care must be taken in this part of the work, particularly for the composition for sky-rockets. When you have four or five pounds of ingredients to mix, which is a sufficient quantity at a time (for a larger proportion will not do so well), first put the different ingredients together, then work them about with your hands, till you think they are pretty well incorporated; after which put them into a lawn sieve with a receiver and top to it; and if, after it is sifted, any remains that will not pass through the sieve, grind it again till fine enough; and, if it be twice sifted, it will not be amiss; but the compositions for wheels and common works are not so material, nor need be so fine. But in all fixed works, from which the fire is to play regular, the ingredients must be very fine, and great care taken in mixing them well together; and observe, that in all compositions wherein are steel or iron filings, the hands must not touch; nor will any works which have iron or steel in their charge keep long in damp weather, unless properly prepared, according to the following directions.

To preserve Steel or Iron Filings.—It sometimes may happen, that fire-works may be required to be kept a long time, or sent abroad; neither of which could be done with brilliant fires, if made with filings unprepared; for this reason, that the saltpetre being of a damp nature, it causes the iron to rust; the consequence of which is, that, when the works are fired, there will appear but very few brilliant sparks, but instead of them a number of red and drossy sparks; and besides, the charge will be so much weakened, that if this was to happen to wheels, the fire will hardly be strong enough to force them round. But, to prevent such accidents, prepare your filings thus:—Melt in a glazed earthen pan some brimstone over a slow fire, and when melted throw in some filings; which keep stirring about till they are covered with brimstone; this you must do while it is on the fire; then take it

off, and stir it very quick till cold, when you must roll it on a board with a wooden roller, till you have broke it as fine as corn powder; after which sift from it as much of the brimstone as you can. There is another method of preparing filings, so as to keep two or three months in winter; this may be done by rubbing them between the strongest sort of brown paper, which before has been moistened with linseed oil. If the brimstone should take fire, you may put it out, by covering the pan close at top: it is not of much signification what quantity of brimstone you use, so that there is enough to give each grain of iron a coat; but as much as will cover the bottom of a pan of about 1 foot diameter, will do for 5 or 6 pound of filings, or cast-iron for gerbes.

To drive or ram Sky-rockets, &c.—Rockets drove over a piercer must not have so much composition put in them at a time as when drove solid; for the piercer, taking up a great part of the bore of the case, would cause the rammer to rise too high; so that the pressure of it would not be so great on the composition, nor would it be drove everywhere equal. To prevent this, observe the following rule:---For those rockets which are rammed over a piercer, let the ladle hold as much composition as, when drove, will raise the drift $\frac{1}{2}$ the interior diameter of the case, and for those drove solid to contain as much as will raise it $\frac{1}{2}$ the exterior diameter of the case: ladles are generally made to go easyin the case, and the length of the scoop is about $1\frac{1}{2}$ of its own diameter.

The charge of rockets must always be drove 1 diameter above the piercer, and on it must be rammed $\frac{1}{3}$ of a diameter of clay: through the middle of which bore a small hole to the composition, that, when the charge is burnt to the top, it may communicate its fire, through the hole, to the stars in the head. Great care must be taken to strike with the mallet, and with an equal force, the same number of strokes to each ladleful of charge; otherwise the rockets will not rise with an uniform motion, nor will the composition burn equal and regular: for which reason they cannot carry a proper tail; for it will break before the rocket has got half way up, instead of reaching from the ground to the top, where the rocket breaks and disperses the stars, rains, or whatever is contained in the head. When you are ramming, keep the drift constantly turning or moving; and when you use the hollow rammers, knock out of them the composition now and then, or the piercer will split them. To a rocket of 4 oz. give to each ladle-full of charge 16 strokes; to a rocket of 1 lb. 28; to a 2 pounder, 36; to a 4-pounder, 42; and to a 6-pounder, 56: but rockets of a larger sort cannot be drove well by hand, but must be rammed with a machine made in the same manner as those for driving piles.

The method of ramming of wheel-cases, or any other sort, in which the charge is drove solid, is much the same as sky-rockets; for the same proportion may be observed in the ladle, and the same number of strokes given, according to their diameters, all cases being distinguished by their diameters. In this manner, a case, whose bore is equal to a rocket of 4 oz. is called a 4-oz. case, and that which is equal to an 8-oz. rocket an 8-oz. case, and so on, according to the different rockets.

Having taught the method of ramming cases in moulds, we shall here say something concerning those filled without moulds; which method, for strong pasted cases, will do extremely well, and save the expence of making so many moulds. The reader must here observe,

when he fills any sort of cases, to place the mould on a perpendicular block of wood, and not on any place that is hollow; for we have found by experience, that when cases were rammed on driving benches, which were formerly used, the works frequently miscarried, on account of the hollow resistance of the benches, which often jarred and loosened the charge in the cases; but this accident never happens when the driving blocks are used.

When cases are to be filled without moulds, proceed thus: Have some nipples made of brass or iron, of several sorts and sizes, in proportion to the cases, and to screw or fix in the top of the driving block; when you have fixed in a nipple, make, at about $1\frac{1}{2}$ inch from it, a square hole in the block, six inches deep and one inch diameter; then have a piece of wood, 6 inches longer than the case intended to be filled, and 2 inches square; on one side of it cut a groove almost the length of the case, whose breadth and depth must be sufficient to cover near $\frac{1}{2}$ the case; then cut the other end to fit the hole in the block, but take care to cut it so that the groove may be of a proper distance from the nipple; this half-mould being made and fixed tight in the block, cut, in another piece of wood nearly of the same length as the case, a groove of the same dimensions as that in the fixed piece; then put the case on the nipple, and with a cord tie it and the 2 half-moulds together, and your case will be ready for filling.

The dimensions of the above-described half-moulds are proportionable for cases of 8 ounces; but notice must be taken, that they differ in size in proportion to the cases. The clay, mentioned in this article, must be prepared after this manner:—Get some clay, in which there is no stones nor sand, and bake it in an oven till quite dry; then take it out and beat it to a powder, and afterwards sift it through a common hair-sieve, and it will be fit for use.

Proportion of Mallets.—The best wood for mallets is dry beech. If a person uses a mallet of a moderate size, in proportion to the rocket, according to his judgment, and if the rocket succeeds, he may depend on the rest, by using the same mallet; yet it will be necessary that cases of different sorts be drove with mallets of different sizes.

The following proportion of the mallets for rockets of any size, from 1 oz. to 6 lb. may be observed; but as rockets are seldom made less than 1 oz. or larger than 6 lb. we shall leave the management of them to the curious; but all cases under 1 oz. may be rammed with a 1 oz. rocket-mallet. Your mallets will strike more solid, by having their handles turned out of the same piece as the head, and made in a cylindrical form. Let their dimensions be worked by the diameters of the rockets: for example, let the thickness of the head be 3 diameters, and its length 4, and the length of the handle 5 diameters, whose thickness must be in proportion to the hand.

Manner of heading Rockets.—When the collar is to be glued on the rocket, you must cut two or three rounds of paper off the case, which will make a shoulder for it to rest upon. Two or three rounds of paper well pasted will be enough for the head, which, when rolled, put the collar on, which must fit the inside of it; then, with the pinching cord pinch the bottom of the head into the groove, and tie it with small twine. To make the caps, cut your paper in round pieces, equal in diameter to twice the length of the cone you intend to make; which pieces being cut into halves, will make two caps each, without wasting

any paper; having formed the caps, paste over each of them a thin white paper, which must be a little longer than the cone, so as to project about $\frac{1}{2}$ an inch below the bottom: this projection of paper, being notched and pasted, serves to fasten the cap to the head.

When you load the heads of your rockets, with stars, rains, serpents, crackers, scrolls, or any thing else, according to your fancy, remember always to put 1 ladleful of meal powder into each head, which will be enough to burst the head, and disperse the stars, or whatever it contains: when the heads are loaded with any sort of cases, let their mouths be placed downwards; and after the heads are filled, paste on the top of them a piece of paper, before you put on the caps. As the size of the stars often differ, it would be needless to give an exact number for each rocket; but this rule may be observed, that the heads may be nearly filled with whatever they are loaded.

Decorations for Sky-rockets.—Sky-rockets bearing the pre-eminence of all fire-works, it will not be improper to treat of their various kinds of decorations, which are directed according to fancy. Some are headed with stars of different sorts, such as tailed, brilliant, white, blue, and yellow stars, &c. some with gold and silver rain; others with serpents, crackers, firescrolls, marrons; and some with small rockets, and many other devices, as the maker pleases.

Dimensions and Poise of Rocket-Sticks.

Weight of the rocket.		Length of the stick.		Thickness at top.	Breadth at top.	Square at bottom.	Poise from the point of the Cone.	
lb.	oz.	F.	in.	Inches.	Inches.	Inches.	F.	in.
6	0	14	0	1,5	1,85	0,75	4	1,5
4	0	12	10	1,25	1,40	0,625	3	9,
2	0	9	4	1,125	1,	0,525	2	9,
1	0	8	2	0,725	0,80	0,375	2	1,
	8	6	6	0,5	0,70	0,25	1	10,4
	4	5	3	0,3750	0,55	0,35	1	8,5
	2	4	1	0,3	0,45	0,15	1	3,
	1	3	6	0,25	0,35	0,10	10	0,
	$\frac{1}{2}$	2	4	0,125	0,20	0,16	8	0,
	$\frac{1}{4}$	1	$10\frac{1}{2}$	0,1	0,15	0,5	5	0,5

The last column on the right, in the above table, expresses the distance from the top of the cone, where the stick, when tied on, should balance the rocket, so as to stand in an equlibrium on one's finger or the edge of a knife. The best wood for the sticks is dry deal, made thus: When you have cut and planed the sticks according to the dimensions given in the table, cut, on one of the flat sides at the top, a groove the length of the rocket, and as broad as the stick will allow; then, on the opposite flat side, cut two notches for the cord, which ties on the rocket, to lie in; one of these notches must be near the top of the stick, and the other facing the neck of the rockets; the distance between these notches may easily be known, for the top of the stick should always touch the head of the rocket. When your rockets and sticks are ready, lay the rockets in the grooves in the sticks, and tie them on. Those who, merely for curiosity, may choose to make rockets

of different sizes from those expressed in the table of dimensions, may find the length of their sticks, by making them, for rockets from $\frac{1}{2}$ oz. to 1 lb. 60 diameters of the rocket long; and for rockets above 1 lb. 50 or 52 diameters will be a good length; their thickness at top may be about $\frac{1}{2}$ a diameter, and their breadth a very little more; their square at bottom is generally equal to $\frac{1}{2}$ the thickness at the top. But, although the dimensions of the sticks be very nicely observed, you must depend only on their balance; for, without a proper counterpoise, your rockets, instead of mounting perpendicularly, will take an oblique direction, and fall to the ground before they are burnt out.

To load Air-Balloons; with the number of Stars, Serpents, Snakes, Rain-Falls, &c. in shells of each nature.

Mortars to throw Aigrettes, &c.—When you fill your shells, you must first put in the serpents, rains, stars, &c. or whatever they are composed of; then the blowing powder; but the shells must not be quite filled. All those things must be put in at the fuze hole; but marrons, being too large to go in at the fuze hole, must be put in before the inside shell be joined. When the shells are loaded, glue and drive in the fuzes very tight. For a cohorn balloon, let the diameter of the fuze hole be $\frac{7}{8}$ of an inch; for a royal balloon, which is near $5\frac{1}{2}$ inches diameter, make the fuze hole $1\frac{1}{6}$ inch diameter; for an 8 inch balloon, $1\frac{3}{8}$ inch; and for a 10-inch balloon, $1\frac{5}{8}$ inch.

Air-balloons are divided into 4 sorts; viz. first, illuminated balloons; second, balloons of serpents; third, balloons of reports, marrons, and crackers; and fourth, compound balloons. The number and quantities of each article for the different shells are as follow:

Cohorn Balloons illuminated.—Meal powder one ounce and a half; corn powder half an ounce; powder for the mortar, two ounces. Length of the fuze composition, $\frac{3}{4}$ of an inch; one ounce drove or rolled stars, as many as will nearly fill the shell.

Cohorn Balloon of Serpents.—Meal powder one ounce and a quarter; corn powder one ounce; powder for the mortar two ounces and a quarter. Length of the fuze composition $\frac{15}{16}$ of an inch: half-ounce cases drove 3 diameters and bounced 3 diameters, and half-ounce cases drove 2 diameters and bounced 4, of each an equal quantity, and as many of them as will fit in easily placed head to tail.

Cohorn Balloons of Crackers and Reports.—Meal powder one ounce and a quarter; corn powder, three quarters of an ounce; powder for the mortar two ounces. Length of the fuze composition $\frac{3}{4}$ of an inch. Reports 4, and crackers of 6 bounces as many as will fill the shell.

Compound Cohorn Balloons.—Meal powder one ounce and four drams; corn powder twelve drams; powder for the mortar two ounces and four drams. Length of the fuze composition $\frac{13}{16}$ of an inch: $\frac{1}{2}$ ounce cases drove $3\frac{1}{2}$ diameters and bounced 2, 16; $\frac{1}{2}$ ounce cases drove four diameters and not bounced 10; blue strung stars, 10; rolled stars, as many as will complete the balloon.

Royal Balloons illuminated.—Meal powder one ounce and eight drams; corn powder twelve drams; powder for the mortar three ounces. Length of the fuze composition $\frac{15}{16}$ of an inch; 2 ounce strung stars, 34; rolled stars, as many as the shell will contain, allowing room for the fuze.

Royal Balloons of Serpents.—Meal powder one ounce; corn powder one ounce and eight drams; powder for the mortar three ounces and eight drams. Length of the fuze composition 1 inch; 1 ounce cases drove $3\frac{1}{2}$ and 4 diameters, and bounced 2, of each an equal quantity, sufficient to load the shell.

Royal Balloons with Crackers and Marrons.—Meal powder one ounce and eight drams; corn powder one ounce and four drams; powder for firing the mortar three ounces. Length of the fuze composition $\frac{14}{16}$ of an inch; reports 12, and completed with crackers of 8 bounces.

Compound Royal Balloons.—Meal powder one ounce and five drams; corn powder one ounce and six drams; powder for the mortar three ounces and twelve drams. Length of the fuze composition 1 inch; $\frac{1}{2}$ ounce cases drove and bounced 2 diameters, 8; 2 ounce cases filled $\frac{3}{8}$ of an inch with star composition, and bounced 2 diameters, 8; silver rain-falls, 10; 2 ounce tailed stars, 16; rolled brilliant stars, 30. If this should not be sufficient to load the shell, you may complete it with gold rain-falls.

Eight-Inch Balloons illuminated.—Meal powder two ounces and eight drams; corn powder one ounce and four drams; powder for the mortar nine ounces. Length of the fuze composition 1 inch $\frac{1}{8}$: 2 ounce drove stars, 48; 2 ounce cases drove with star composition $\frac{3}{8}$ of an inch, and bounced 3 diameters, 12; and the balloon completed with 2 ounce drove brilliant stars.

Eight-Inch Balloons of Serpents.—Meal powder two ounces; corn powder two ounces; powder for the mortar nine ounces and eight drams. Length of the fuze composition 1 inch $\frac{3}{16}$: 2 ounce cases drove $1\frac{1}{2}$ diameter and bounced 2, and 1 ounce cases drove 2 diameters and bounced $2\frac{1}{2}$, of each an equal quantity sufficient for the shell. The star-composition driven in bounced cases must be managed thus: First, the cases must be pinched close at one end, then the corn-powder put in for a report, and the case pinched again close to the powder, only leaving a small vent for the star composition, which is drove at top, to communicate to the powder at the bounce end.

Compound Eight-Inch Balloons.—Meal powder two ounces and eight drams; corn powder one ounce and twelve drams; powder for the mortar nine ounces and four drams. Length of the fuze composition $\frac{1}{8}$: 4 ounce cases drove with star composition $\frac{3}{8}$ of an inch, and bounced 3 diameters, 16; 2 ounce tailed stars, 16; 2 ounce drove brilliant stars, 12; silver rain-falls, 20; 1 ounce drove blue stars, 20; and 1 ounce cases drove and bounced 2 diameters, as many as will fill the shell.

Another of Eight-Inches.—Meal powder two ounces and eight drams; corn powder one ounce and twelve drams; powder for the mortar nine ounces and four drams. Length of the fuze composition 1 inch $\frac{1}{8}$: crackers of 6 reports, 10; gold rains, 14; 2 ounce cases drove with star composition $\frac{3}{8}$ of an inch, and bounced 2 diameters, 16; 2 ounce tailed stars, 16; 2 ounce drove brilliant stars, 12; silver rains, 10; 1 ounce drove blue stars, 20; and 1 ounce cases drove with a brilliant charge 2 diameters and bounced 3, as many as the shell will hold.

A Compound Ten-Inch Balloon.—Meal powder three ounces and four drams; corn powder two ounces and eight drams; powder for the mortar twelve ounces and eight drams. Length of the fuze composition $\frac{15}{16}$ of an inch: 1 ounce cases drove and bounced 3 diameters, 16;

Crackers of 8 reports, 12; 4 ounce cases drove $\frac{1}{2}$ inch with star-composition, and bounced 2 diameters, 14; 2 ounce cases drove with brilliant fire $1\frac{1}{4}$ diameter, and bounced 2 diameters, 16: 2 ounce drove brilliant stars, 30: 2 ounce drove blue stars, 3; gold rains, 20; silver rains, 20. After all these are put in, fill the remainder of the case with tailed and rolled stars.

Ten-Inch Balloons of three Charges.—Meal powder three ounces; corn powder three ounces and two drams; powder for the mortar thirteen ounces. Length of the fuze composition 1 inch. The shell must be loaded with 2 ounce cases, drove with star composition $\frac{1}{4}$ of an inch, and on that 1 diameter of gold fire, then bounced 3 diameters; or with 2 ounce cases first filled 1 diameter with gold fire, then $\frac{1}{4}$ of an inch with star composition, and on that $1\frac{1}{4}$ diameter of brilliant fire. These cases must be well secured at top of the charge, lest they should take fire at both ends: but their necks must be larger than the common proportion.

To make Balloon Fuzes.—Fuzes for air-balloons are sometimes turned out of dry beach, with a cup at top to hold the quick-match; but, if made with pasted paper, they will do as well; the diameter of the former for fuzes for cohorn balloons must be half an inch; for a royal fuze five-eighths of an inch; for an eight-inch fuze three-fourths of an inch; and for a ten-inch fuze, seven-eighths of an inch. Having rolled your cases, pinch and tie them almost close at one end; then drive them down, and let them dry. Before you begin to fill them, mark on the outside of the case the length of the charge required, allowing for the thickness of the bottom; and when you have rammed in the composition, take two pieces of quick-match about six inches long, and lay one end of each on the charge, and then a little meal powder, which ram down hard; the loose ends of the match double up into the top of the fuze, and cover it with a paper cap to keep it dry. When you put the shells in the mortars uncap the fuzes, and pull out the loose ends of the match, and let them hang on the sides of the balloons. The use of the match is to receive the fire from the powder in the chamber of the mortar, in order to light the fuze; the shell being put in the mortar with the fuze uppermost, and exactly in the centre, sprinkle over it a little meal-powder, and it will be ready to be fired. Fuzes made of wood must be longer than those of paper, and not bored quite through, but left solid about half an inch at bottom: and when you use them, saw them off to a proper length, measuring the charge from the cup at top.

Tourbillons.—Having filled some cases within about $1\frac{1}{2}$ diameter, drive in a ladleful of clay; then pinch their ends close, and drive them down with a mallet. When done, find the centre of gravity of of the connected cases, and tie a stick, which should be half an inch broad at the middle, and run a little narrower to the ends: these sticks must have their ends turned upwards, so that the cases may turn horizontally on their centres; at the opposite sides of the cases, at each end, bore a hole close to the clay with a gimblet, the size of the neck of a common case of the same nature; from these holes draw a line round the case, and at the upper part of the case bore a hole with the same gimblet, within half diameter of each line towards the centre; then from one hole to the other draw a right line, and bore two holes; then from these holes to the other two lead a quick-match,

over which paste a thin paper. When you fire tourbillons, lay them on a smooth table, with their sticks downwards, and burn the leader through the middle with a port-fire. They should spin three or four seconds on the table before they rise, which is about the time the composition will be burning from the side holes to those at bottom. To tourbillons may be fixed reports in this manner: In the centre of the case at top make a small hole, and in the middle of the report make another; then place them together, and tie on the report, and with a single paper secure it from fire: this done, your tourbillon is completed. By this method you may fix on tourbillons small cones of stars, rains, &c. but be careful not to load them too much. One-eighth of an inch will be enough for the thickness of the sticks, and their length equal to that of the cases.

To make Mortars to throw Aigrettes, and to load and fire them.—Mortars to throw aigrettes are generally made of pasteboard, of the same thickness as balloon mortars, and $2\frac{1}{2}$ diameters long in the inside from the top of the foot: the foot must be made of elm without a chamber, but flat at top, and in the same proportion as those for balloon mortars; these mortars must also be bound round with a cord as before mentioned: sometimes eight or nine of these mortars, of about three or four inches diameter, are bound altogether so as to appear but one: but when they are made for this purpose, the bottom of the foot must be of the same diameter as the mortars, and only $\frac{1}{2}$ diameter high.—Your mortars being bound well together, fix them on a heavy solid block of wood. To load these mortars, first put on the inside bottom of each a piece of paper, and on it spread $1\frac{1}{2}$ oz. of meal and corn powder mixed; then tie your serpents up in parcels with quick-match, and put them in the mortar with their mouths downwards; but take care the parcels do not fit too tight in the mortars, and that all the serpents have been well primed with powder wetted with spirits of wine. On the top of the serpents in each mortar lay some paper or tow; then carry a leader from one mortar to the other all round, and then from all the outside mortars into that in the middle. These leaders must be put between the cases and the sides of the mortar, down to the powder at bottom: in the centre of the middle mortar fix a fire-pump, or brilliant fountain, which must be open at bottom, and long enough to project out of the mouth of the mortar; then paste paper on the tops of all the mortars.

Mortars thus prepared are called a *nest of serpents.* When you would fire these mortars, light the fire-pump, which, when consumed, will communicate to all the mortars at once by means of the leaders. For mortars of 6, 8, or 10 inches diameter, the serpents should be made in 1 and 2 ounce cases, 6 or 7 inches long, and fired by a leader brought out of the mouth of the mortar, and turned down the outside, and the end of it covered with paper, to prevent the sparks of the other works from setting it on fire. For a six-inch mortar, let the quantity of powder for firing be 2 oz. for an eight-inch $2\frac{3}{4}$ oz. and for a ten-inch $3\frac{3}{4}$ oz. Care must be taken in these as well as small mortars, not to put the serpents in too tight, for fear of bursting the mortars. These serpents may be loaded with stars, crackers, &c.

If the mortars, when loaded, are sent to any distance, or liable to be much moved, the firing powder should be secured from getting amongst the serpents, which would endanger the mortars, as well as

hurt their performance. To prevent which, load your mortars thus:—First put in the firing powder, and spread it equally about; then cut a round piece of blue touch-paper, equal to the exterior diameter of the mortar, and draw on it a circle equal to the interior diameter of the mortar, and notch it all round as far as that circle; then paste that part which is notched, and put it down the mortar close to the powder, and stick the pasted edge to the mortar: this will keep the powder always smooth at bottom, so that it may be moved or carried anywhere without receiving damage. The large single mortars are called *pots des aigrettes.*

Making, loading, and firing of Pots des Brins.—These are formed of pasteboard, and must be rolled pretty thick. They are usually made three or four inches diameter, and four diameters long: and pinched with a neck at one end, like common cases. A number of these are placed on a plank thus: Having fixed on a plank two rows of wooden pegs, cut in the bottom of the plank a groove the whole length under each row of pegs; then, through the centre of each peg, bore a hole down to the groove at bottom, and on every peg fix and glue a pot, whose mouth must fit tight to the peg: through all the holes run a quick-match, one end of which must go into the pot, and the other into the groove, which must have a match laid in it from end to end, and covered with paper, so that when lighted at one end it may discharge the whole almost instantaneously In all the pots put about 1 oz. of meal and corn powder; then in some put stars, and in others rains, snakes, serpents, crackers, &c. when they are all loaded, paste paper over their mouths. Two or three hundred of these pots being fired together make a very pretty show, by affording so great a variety of fires.

Pots des Saucissons are generally fired out of large mortars without chambers, the same as those for aigrettes, only somewhat stronger. Saucissons are made of 1 and 2 ounce cases, 5 or 6 inches long, and choaked in the same manner as serpents. Half the number which the mortar contains must be drove $1\frac{1}{2}$ diameter with composition, and the other half 2 diameters, so that when fired they may give 2 volleys of reports. But if the mortars are very strong, and will bear a sufficient charge to throw the saucissons very high, you may make 3 volleys of reports, by dividing the number of cases into 3 parts, and making a difference in the height of the charge. After they are filled, pinch and tie them at top of the charge almost close; only leaving a small vent to communicate the fire to the upper part of the case, which must be filled with corn powder very near the top; then pinch the end quite close, and tie it: after this is done, bind the case very tight with waxed pack-thread, from the choak at top of the composition to the end of the case; this will make the case very strong in that part, and cause the report to be very loud. Saucissons should be rolled a little thicker of paper than the common proportion. When they are to be put in the mortar, they must be primed in their mouths, and fired by a case of brilliant fire fixed in their centre. The charge for these mortars should be one-sixth or one-eighth more than for pots des aigrettes of the same diameters.

Different Kinds of Rockets, with their Appendages and Combinations.

To fix one Rocket on the top of another.—When sky-rockets are thus managed, they are called towering rockets, on acounting of their mount-

ing so very high. Towering rockets are made after this manner:—Fix on a pound-rocket a head without a collar; then take a 4-ounce rocket, which may be headed or bounced, and rub the mouth of it with meal powder wetted with spirits of wine: when done, put it in the head of the large rocket with its mouth downwards; but before you put it in, stick a bit of quick-match in the hole of the clay of the pound rocket, which match should be long enough to go a little way up the bore of the small rocket, to fire it when the large is burnt out; the 4-ounce rocket being too small to fill the head of the other, roll round it as much tow as will make it stand upright in the centre of the head: the rocket being thus fixed, paste a single paper round the opening of the top of the head of the large rocket. The large rocket must have only half a diameter of charge rammed above the piercer; for, if filled to the usual height, it would turn before the small one takes fire, and entirely destroy the intended effect: when one rocket is heated with another, there will be no occasion for any blowing powder; for the force with which it sets off will be sufficient to disengage it from the head of the first fired rocket. The sticks for these rockets must be a little longer than for those headed with stars, rains, &c.

Caduceus Rockets, in rising, form too spiral lines, or double worm, by reason of their being placed obliquely, one opposite the other; and their counterpoise in their centre, which causes them to rise in a vertical direction. Rockets for this purpose must have their ends choaked close, without either head or bounce, for a weight at top would be a great obstruction to their mounting; though I have known them sometimes to be bounced, but then they did not rise so high as those that were not; nor do any caduceus rockets ascend so high as single, because of their serpentine motion, and likewise the resistance of air, which is much greater than two rockets of the same size would meet with if fired singly.

For fixing these rockets the sticks must have all their sides alike; which sides should be equal to the breadth of a stick proper for a sky-rocket of the same weight as those you intend to use, and to taper downwards as usual, long enough to balance them, one length of a rocket from the cross stick; which must be placed from the large stick 6 diameters of one of the rockets, and its length 7 diameters; so that each rocket, when tied on, may form with the large stick an angle of 60 degrees. In tying on the rockets, place their heads on the opposite sides of the cross stick, and their ends on the opposite sides of the long stick; then carry a leader from the mouth of one into that of the other. When these rockets are to be fired, suspend them between two hooks or nails, then burn the leader through the middle, and both will take fire at the same time. Rockets of 1 lb. are a good size for this use.

Honorary Rockets are the same as sky-rockets, except that they carry no head nor report, but are closed at top, on which is fixed a cone; then on the case, close to the top of the stick, you tie on a 2-ounce case, about 5 or 6 inches long, filled with a strong charge, and pinched close at both ends; then, in the reverse sides, at each end bore a hole in the same manner as in tourbillons; from each hole carry a leader into the top of the rocket. When the rocket is fired, and arrived to it proper height, it will give fire to the case at top; which will cause both rocket and stick to spin very fast in their return, and represent a worm of fire descending to the ground. There is another method of placing the

small case, which is by letting the stick rise a little above the top of the rocket, and tying the case to it, so as to rest on the rocket: these rockets have no cones. There is also a third method by which they are managed, which is thus:—In the top of a rocket fix a piece of wood, in which drive a small iron spindle: then make a hole in the middle of the small case, through which put the spindle: then fix on the top of it a nut, to keep the case from falling off; when this is done, the case will turn very fast without the rocket; but this method does not answer so well as either of the former.

To divide the Tail of a Sky-Rocket so as to form an Arch when ascending.—Having some rockets made, and headed according to fancy, and tied on their sticks; get some sheet tin, and cut it into round pieces about 3 or 4 inches diameter; then on the stick of each rocket, under the mouth of the case, fix one of these pieces of tin 16 inches from the rocket's neck, and support it by a wooden bracket, as strong as possible. The use of this is, that when the rocket is ascending, the fire will play with great force on the tin, which will divide the tail in such a manner that it will form an arch as it mounts, and will have a very good effect when well managed: if there is a short piece of port-fire, of a strong charge, tied to the end of the stick, it will make a great addition; but this must be lighted before you fire the rocket.

To make several Sky-Rockets rise in the same Direction, and equally distant from each other.—Take six or any number of sky-rockets, of what size you please, then cut some strong packthread into pieces of 3 or 4 yards long, and tie each end of these pieces to a rocket in this manner:—Having tied one end of your packthread round the body of one rocket, and the other end to another, take a second piece of pack-thread, and make one end of it fast to one of the rockets already tied, and the other end to a third rocket, so that all the rockets, excepting the two outside, will be fastened to two pieces of packthread: the length of thread from one rocket to the other may be what the maker pleases; but the rockets must be all of a size, and their heads filled with the same weight of stars, rains, &c.

Having thus done, fix in the mouth of each rocket a leader of the same length; and when you are going to fire them, hang them almost close; then tie the ends of the leaders together, and prime them: this prime being fired, all the rockets will mount at the same time, and divide as far as the strings will allow; which division they will keep, provided they are all rammed alike, and well made. They are called by some chained rockets.

Signal Sky-Rockets are made of several kinds, according to the different signals intended to be given; but in artificial fire-works, two sorts are only used, which are one with reports and the other without; but those for the use of the navy and army are headed with stars, serpents, &c. Rockets which are to be bounced, must have their cases made $1\frac{1}{2}$ or 2 diameters longer than the common proportion; and after they are filled, drive in a double quantity of clay, then bounce and pinch them after the usual manner, and fix on each a cap.

Signal sky-rockets without bounces, are only sky-rockets closed and capped: these are very light, therefore do not require such heavy sticks as those with loaded heads; for which reason you may cut one length of the rocket off the stick, or else make them thinner. Signal

rockets with reports are fired in small flights; and often both these, and those without reports are used for a signal to begin firing a collection of works.

To fix a Sky-Rocket with its Stick on the top of another.—Rockets thus managed make a pretty appearance by reason of a fresh tail being seen when the second rocket takes fire, which will mount to a great height. The method of preparing these rockets is thus:—Having filled a two-pounder, which must be filled only half a diameter above the piercer, and its head not more than ten or twelve stars; the stick of this rocket must be made a little thicker than common; and, when made, cut it in half the flat way, and in each half make a groove, so that when the two halves are joined, the hollow made by the grooves may be large enough to hold the stick of a half-pound rocket: which rocket make and head as usual. Put the stick of this rocket into the hollow of the large one, so far that the mouth of the rocket may rest on the head of the two-pounder; from whose head carry a leader into the mouth of the small rocket; which being done, your rockets will be ready for firing.

To fix two or more Sky-Rockets on one Stick.—Two, three, or six sky-rockets, fixed on one stick, and fired together, make a grand and beautiful appearance; for the tails of all will seem but as one of an immense size, and the breaking of so many heads at once will resemble the bursting of an air-balloon. The management of this device requires a skilful hand; but if the following instructions be well observed, even by those who have not made a great progress in this art, there will be no doubt of the rockets having the desired effect.—Rockets for this purpose must be made with the greatest exactness, all rammed by the same hand, in the same mould, and out of the same proportion of composition; and after they are filled and headed, must all be of the same weight. The stick must also be well made and proportioned to the following directions:—First, supposing your rockets to be half-pounders, whose sticks are 6 feet 6 inches long, then if 2, 3, or 6 of these, are to be fixed on one stick, let the length of it be 9 feet 9 inches; then cut the top of it into as many sides as there are rockets, and let the length of each side be equal to the length of one of the rockets without its head; and in each side cut a groove as usual; then from the grooves plane it round down to the bottom, where its thickness must be equal to half the top of the round part. As their thickness cannot be exactly ascertained, we shall give a rule which generally answers for any number of rockets above two. The rule is this: that the stick at top must be thick enough, when the grooves are cut, for all the rockets to lie, without pressing each other, though as near as possible.

When only 2 rockets are to be fixed on 1 stick, let the length of the stick be the last given proportion, but shaped after the common method, and the breadth and thickness double the usual dimensions. The point of poise must be in the usual place (let the number of rockets be what they will). If sticks made by the above directions should be too heavy, plane them thinner; and, if too light, make them thicker; but always make them of the same length.

When more than 2 rockets are tied on 1 stick, there will be some danger of their flying up without the stick, unless the following precaution is taken: for cases being placed on all sides, there can be no

notches for the cord which ties on the rocket to lie in; therefore, instead of notches, drive a small nail in each side of the stick, between the necks of the cases; and let the cord, which goes round their necks, be brought close under the nails: by this means the rockets will be as secure as when tied on singly. Your rockets being thus fixed, carry a quick-match, without a pipe, from the mouth of one rocket to the other; this match being lighted will give fire to all at once.

Though the directions already given may be sufficient for these rockets, we shall here add an improvement on a very essential part of this device, which is that of hanging the rockets to be fired; for before the following method was hit upon, many essays proved unsuccessful. Instead, therefore, of the old and common manner of hanging them on nails or hooks, make use of this contrivance: Have a ring made of strong iron wire, large enough for the stick to go in as far as the mouths of the rockets; then let this ring be supported by a small iron, at some distance from the post or stand to which it is fixed; then have another ring, fit to receive and guide the small end of the stick. Rockets thus suspended will have nothing to obstruct their fire; but when they are hung on nails or hooks, in such a manner that some of their mouths are against or upon a rail, there can be no certainty of their rising in a vertical direction.

To fire Sky-Rockets without Sticks.—You must have a stand of a block of wood, a foot diameter, and make the bottom flat, so that it may stand steady: in the centre of the top of this block draw a circle $2\frac{1}{2}$ inches diameter, and divide the circumference of it into 3 equal parts; then take 3 pieces of thick iron wire, each about 3 feet long, and drive them into the block, 1 at each point made on the circle; when these wires are drove in deep enough to hold them fast and upright, so that the distance from one to the other is the same at top as at bottom, the stand is complete.

The stand being thus made, prepare your rockets thus: Take some common sky-rockets of any size, and head them as you please; then get some balls of lead, and tie to each a small wire 2 or $2\frac{1}{2}$ feet long, and the other end of each wire tie to the neck of a rocket. These balls answer the purpose of sticks when made of a proper weight, which is about two-thirds the weight of the rocket; but when they are of a proper size, they will balance the rocket in the same manner as a stick at the usual point of poise. To fire these, hang them, one at a time, between the tops of the wires, letting their heads rest on the point of the wires, and the balls hang down between them: if the wires should be too wide for the rockets, press them together till they fit; and if too close force them open; the wires for this purpose must be softened, so as not to have any spring, or they will not keep their position when pressed close or opened.

Rain-falls and Stars for Sky-Rockets, double and single.—Gold and silver-rain compositions are drove in cases that are pinched quite close at one end; if you roll them dry, 4 or 5 rounds of paper will be strong enough; but if they are pasted 3 rounds will do; and the thin sort of cartridge-paper is best for those small cases, which in rolling you must not turn down the inside edge as in other cases, for a double edge would be too thick for so small a bore. The moulds for rain-falls should be made of brass, and turned very smooth in the inside; or the cases, which are so very thin, would tear in coming out; for the

charge must be drove in tight; and the better the case fits the mould, the more driving it will bear. These moulds have no nipple, but instead thereof they are made flat. As it would be very tedious and troublesome to shake the composition out of such small ladles as are used for these cases, it will be necessary to have a funnel made of thin tin, to fit on the top of the case, by the help of which you may fill them very fast. For single rain-falls for 4-ounce rockets, let the diameter of the former be two-sixteenths of an inch, and the length of the case 2 inches; for 8-ounce rockets four-sixteenths, and 2 diameters of the rocket long; for 1-pound rockets five-sixteenths, and 2 diameters of the rocket long; for 2-pound rockets five-sixteenths, and $3\frac{1}{2}$ inches long; for 4-pound rockets six-sixteenths, and $4\frac{1}{2}$ inches long; and for 6-pounders seven-sixteenths diameter, and 5 inches long.

Of double rain-falls there are two sorts: for example, some appear first like a star, and then as rain; and some appear first as rain, and then like a star. When you would have stars first, you must fill the cases, within $\frac{1}{2}$ an inch of the top, with rain-composition, and the remainder with star-composition; but when you intend the rain should be first, drive the case $\frac{1}{2}$ an inch with star-composition, and the rest with rain. By this method may be made many changes of fire; for in large rockets you may make them first burn as stars, then rain, and again as stars; or they may first show rain, then stars, and finish with a report; but when they are thus managed, cut open the first rammed end, after they are filled and bounced, at which place prime them. The star-composition for this purpose must be a little stronger than for rolled stars.

Strung Stars.—First take some thin paper, and cut it into pieces of $1\frac{1}{2}$ inch square or thereabouts; then on each piece lay as much dry star-composition as you think the paper will easily contain; then twist up the paper as tight as you can; when done, rub some paste on your hands, and roll the stars between them; then set them to dry. Your stars being thus made, get some flax or fine tow, and roll a little of it over each star; then paste your hands, and roll the stars as before, and set them again to dry. When they are quite dry, with a piercer make a hole through the middle of each, into which run a cotton quick-match, long enough to hold 10 or 12 stars, at 3 or 4 inches distance; but any number of stars may be strung together by joining the match.

Tailed Stars.—These are called tailed stars, because there are a great number of sparks issue from them, which represent a tail like that of a comet. Of these there are two sorts, which are rolled and drove; when rolled, they must be moistened with a liquor made of $\frac{1}{2}$ a pint of spirits of wine and $\frac{1}{2}$ a gill of thin size: of this as much as will wet the composition enough to make it roll easy; when they are rolled, sift meal powder over them, and set them to dry. When tailed stars are drove, the composition must be moistened with spirits of wine only, and not made wet as for rolling: 1 and 2 oz. cases, rolled dry, are best for this purpose; and when they are filled, unrol the case within 3 or 4 rounds of the charge, and all that you unrol cut off; then paste down the loose edge: 2 or 3 days after the cases are filled, cut them in pieces five or six-eighths of an inch in length: then melt some wax, and dip one end of each piece into it, so as to cover the

composition: the other end must be rubbed with meal powder wetted with spirits of wine.

Drove Stars.—Cases for drove stars are rolled with paste, but are made very thin of paper. Before you begin to fill them, damp the composition with spirits of wine that has had some camphor dissolved in it: you may ram them indifferently hard, so that you do not break or sack the case; to prevent which, they should fit tight in the mould. They are drove in cases of several sizes, from 8 drams to 4 oz. When they are filled in $\frac{1}{2}$ oz. cases, cut them in pieces of $\frac{3}{4}$ of an inch long; if 1 oz. cases, cut them in pieces of 1 inch; if 2-ounce cases, cut them in pieces of $1\frac{1}{4}$ inch long; and if 4 oz. cases, cut them in pieces of $1\frac{1}{2}$ inch long: having cut your stars of a proper size, prime both ends with wet meal powder. These stars are seldom put in rockets, they being chiefly intended for air-balloons, and drove in cases, to prevent the composition from being broke by the force of the blowing powder in the shell.

Rolling Stars are commonly made about the size of a musket ball; though they are rolled of several sizes, from the bigness of a pistol ball to one inch diameter; and sometimes very small, but are then called sparks. Great care must be taken in making stars, first, that the several ingredients are reduced to a fine powder; secondly, that the composition is well worked and mixed. Before you begin to roll, take about a pound of composition, and wet it with the following liquid enough to make it stick together and roll easy: Spirits of wine 1 quart, in which dissolve $\frac{1}{4}$ of an ounce of isinglass. If a great quantity of composition be wetted at once, the spirit will evaporate, and leave it dry, before you can roll it into stars. Having rolled up one proportion, shake the stars in meal powder, and set them to dry, which they will do in 3 or 4 days; but if you should want them for immediate use, dry them in an earthen pan over a slow heat, or in an oven. It is very difficult to make the stars all of an equal size when the composition is taken up promiscuously with the fingers; but by the following method they may be made very exact: When the mixture is moistened properly, roll it on a flat smooth stone, and cut it into square pieces, making each square large enough for the stars you intend. There is another method used by some to make stars, which is by rolling the composition in long pieces, and then cutting off the star, so that each star will be of a cylindrical form: but this method is not so good as the former; for, to make the composition roll this way, it must be made very wet, which makes the stars heavy, as well as weakens them. All stars must be kept as much from air as possible, otherwise they will grow weak and bad.

Scrolls of Sky-Rockets.—Cases for scrolls should be made 4 or 5 inches in length, and their interior diameter three-eighths of an inch: one end of these cases must be pinched quite close, before you begin to fill; and, when filled, close the other end: then in the opposite sides make a small hole at each end to the composition, in the same manner as in tourbillons, and prime them with wet meal powder. You may put in the head of a rocket as many of these cases as it will contain: being fired, they turn very quick in the air, and form a scroll or spiral line. They are generally filled with a strong charge, as that of serpents or brilliant fire.

Swarmers, or small Rockets.—Rockets that go under the denomination of *swarmers,* are those from 2 oz. downwards. These rockets are fired sometimes in flights, and in large water-works, &c. Swarmers of 1 and 2 oz. are bored, and made in the same manner as large rockets, except that, when headed, their heads must be put on without collars: the number of strokes for driving 1 oz. must be 8, and for 2 oz. 12.

All rockets under 1 oz. are not bored, but must be filled to the usual height with composition, which generally consists of fine meal powder 4 oz. and charcoal or steel-dust 2 drams: the number of strokes for ramming these small swarmers is not material, provided they are rammed true, and moderately hard. The necks of unbored rockets must be in the same proportion as in common cases.

Stands for Sky-rockets.—Care must be taken, in placing the rockets when they are to be fired, to give them a vertical direction at their first setting out; which may be managed thus:—Have two rails of wood, of any length, supported at each end by a perpendicular leg, so that the rails be horizontal, and let the distance from one to the other be almost equal to the length of the sticks of the rockets intended to be fired; then in the front of the top rail drive square hooks at 8 inches distance, with their points turning sidewise, so that, when the rockets are hung on them, the points will be before the sticks, and keep them from falling or being blown off by the wind: in the front of the rail at bottom must be staples, drove perpendicular under the hooks at top; through these staples put the small ends of the rocket-sticks. Rockets are fired by applying a lighted port-fire to their mouths. When sky-rockets are made to perfection, and fired, they will stand 2 or 3 seconds on the hook before they rise, and then mount up briskly, with a steady motion, carrying a large tail from the ground all the way up, and just as they turn break and disperse the stars.

Girandole Chests for Flights of Rockets.—These are generally composed of four sides of equal dimensions; but may be made of any diameter, according to the number of rockets designed to be fired: its height must be in proportion to the rockets, but must always be a little higher than the rockets with their sticks. When the sides are joined, fix in the top, as far down the chest as the length of one of the rockets with its cap on. In this top, make as many square or round holes to receive the rocket-sticks, as you intend to have rockets; but let the distance between them be sufficient for the rockets to stand without touching one another; then from one hole to another cut a groove large enough for a quick-match to lie in: the top being thus fixed, put in the bottom, at about 1½ foot distance from the bottom of the chest; in this bottom must be as many holes as in the top, and all to correspond; but these holes need not be so large as those in the top.

To prepare your chest, you must lay a quick-match, in all the grooves, from the hole to hole; then take some sky-rockets, and rub them in the mouth with wet meal powder, and put a bit of match up the cavity of each; which match must be long enough to hang a little below the mouth of the rocket. Your rockets and chest being prepared according to the above directions, but the sticks of the rockets through the holes in the top and bottom of the chest, so that all their mouths may rest on the quick match in the grooves: by which all the rockets will be fired at once; for, by giving fire to any part of the match, it will communicate to all the rockets in an instant. As it

would be rather troublesome to direct the sticks from the top to the proper holes in the bottom, it will be necessary to have a small door in one of the sides, which, when opened, you may see how to place the sticks. Flights of rockets being seldom set off at the beginning of any fire-works, they are in danger of being fired by the sparks from wheels, &c. therefore, to preserve them, a cover should be made to fit on the chest, and the door in the side kept shut.

Serpents or Snakes for Pots of Aigrettes, small Mortars, Sky-rockets, &c. Serpents for this use are made from $2\frac{1}{2}$ inches to 7 inches long, and their formers from 3-16ths to 5-8ths of an inch diameter; but the diameter of the cases must always be equal to 2 diameters of the former. They are rolled and choaked like other cases, and filled with composition from 5-8ths of an inch to $1\frac{1}{2}$ inch high, according to the size of the mortars or rockets they are designed for; and the remainder of the cases bounced with corn powder, and afterwards their ends pinched and tied close: before they are used, their mouths must be primed with wet meal-powder.

Leaders, or Pipes of Communication.—The best paper for leaders is elephant; which you cut into long slips 2 or 3 inches broad, so that they may go 3 or 4 times round the former, but not more: when they are very thick, they are too strong for the paper which fastens them to the works, and will sometimes fly off without leading the fire. The formers for these leaders are made from 2 to 6-16ths of an inch diameter; but 4-16ths is the size generally made use of. The formers are made of smooth brass wire: when you use them, rub them over with grease, or keep them wet with paste, to prevent their sticking to the paper, which must be pasted all over. In rolling of pipes, make use of a rolling-board, but use it lightly: having rolled a pipe, draw out the former with one hand, holding the pipe as light as possible with the other; for, if it press against the former, it will stick and tear the paper. Make your leaders of different lengths, or in clothing of works you will cut a great many to waste. Leaders for marron batteries must be made of strong cartridge paper.

Crackers.—Cut some cartridge paper into pieces $3\frac{1}{2}$ inches broad, and one foot long; one edge of each fold down lengthwise about $\frac{3}{4}$ of an inch broad; then fold the double edge down $\frac{1}{4}$ of an inch, and turn the single edge back half over the double fold; then open it, and lay all along the channel, which is formed by the folding of the paper, some meal-powder; then fold it over and over till all the paper is doubled up, rubbing it down every turn; this done, bend it backwards and forwards, $2\frac{1}{2}$ inches, or thereabouts, at a time, as often as the paper will allow; then hold all these folds flat and close, and with a small pinching cord give one turn round the middle of the cracker, and pinch it close; then bind it with a packthread as tight as you can; then, in the place where it was pinched, prime one end of it, and cap it with touch-paper. When these crackers are fired, they will give a report at every turn of the paper: if you would have a great number of bounces, you must cut the paper longer, or join them after they are made; but, if they are made very long before they are pinched, you must have a piece of wood with a groove in it, deep enough to let in half the cracker; this will hold it straight while it is pinching.

Single Reports.—Cases for reports are generally rolled on one and two oz. formers, and seldom made larger but on particular occasions;

they are made from two to four inches long, and very thick of paper. Having rolled a case, pinch one end quite close, and drive it down: then fill the case with corn powder, only leaving room to pinch it at top; but before you pinch it, put in a piece of paper at top of the powder. Reports are fired by a vent, bored in the middle, or at one end, just as required.

Marrons.—Formers for marrons are from $\frac{3}{4}$ of an inch to $1\frac{1}{2}$ diameter. Cut the paper for the cases twice the diameter of the former broad, and long enough to go three times round: when you have rolled a case, paste down the edge and tie one end close; then with the former drive it down to take away the wrinkles, and make it flat at bottom; then fill the case with corn powder one diameter and $\frac{1}{4}$ high, and fold down the rest of the case tight on the powder. The marron being thus made, wax some strong pack-thread with shoemakers' wax; this thread wind up in a ball, then unwind two or three yards of it, and that part which is near the ball make fast to a hook; then take a marron, and stand as far from the hook as the pack-thread will reach, and wind it lengthwise round the marron as close as you can, till it will hold no more that way; then turn it, and wind the pack-thread on the short way, then lengthwise again, and so on till the paper is all covered; then make fast the end of the pack-thread, and beat down both ends of the marron to bring it in shape. The method of firing marrons is by making a hole at one end with an awl, and putting in a piece of quick-match then take a piece of strong paper, in which wrap up the marron with two leaders, which must be put down to the vent, and the paper tied tight round them with small twine: these leaders are bent on each side, and their loose ends tied to other marrons, and are nailed in the middle to the rail of the stand. The use of winding the pack-thread in a ball is, that you may let it out as you want it, according to the quantity the marron may require; and that it may not be tied in knots, which would spoil the marron.

Marron Batteries, if well managed, will keep time to a march, or a slow piece of music. Marron batteries are made of several stands, with a number of cross rails for the marrons; which are regulated by leaders, by cutting them of different lengths, and nailing them tight, or loose, according to the time of the music. In marron batteries you must use the large and small marrons, and the nails for the pipes must have flat heads.

Line Rockets—Are made and drove as the sky-rockets, but have no heads, and the cases must be cut close to the clay: they are sometimes made with six or seven changes, but in general not more than four or five. The method of managing those rockets is thus:—First, have a piece of light wood, the length of one of the rockets, turned round about $2\frac{1}{2}$ inches diameter, with a hole through the middle lengthwise, large enough for the line to go easily through: if you design four changes, have four grooves cut in the swivel, one opposite the other, to lay the rockets it.

The mouths of the rockets being rubbed with wet meal powder, lay them in the grooves head to tail, and tie them fast; from the tail of the first rocket carry a leader to the mouth of the second, and from the second to the third, and so on to as many as there are on the swivel, making every leader very secure; but, in fixing these pipes, take care that the quick match does not enter the bores of the rockets: the

rockets being fixed on the swivel and ready to be fired, have a line 100 yards long, stretched and fixed up tight, at any height from the ground; but be sure to place it horizontally: this length of line will do for $\frac{1}{2}$lb. rockets; but if larger, the line must be longer. Before you put up the line, put one end of it through the swivel; and, when you fire the line-rocket, let the mouth of that rocket which you fire first face that end of the line where you stand; then the first rocket will carry the rest to the other end of the line, and the second will bring them back; and so they will run out and in, according to the number of rockets: at each end of the line there must be a piece of flat wood for the rocket to strike against, or its force will cut the line. Let the line be well soaped, and the hole in the swivel very smooth.

Different Decorations for Line Rockets.—To line rockets may be fixed great variety of figures, such as flying dragons, Mercuries, ships, &c. Or they may be made to run on the line like a wheel; which is done in this manner: Have a flat swivel made very exact, and on it tie two rockets obliquely, one on each side, which will make it turn round all the way it goes, and form a circle of fire; the charge for these rockets should be a little weaker than common. If you would shew two dragons fighting, get two swivels made square, and on each tie three rockets together on the under side; then have two flying dragons made of tin, and fix one of them on the top of each swivel, so as to stand upright; in the mouth of each dragon put a small case of common fire, and another at the end of the tail; you may put two or three port-fires, of a strong charge, on one side of their bodies, to shew them. This done, put them on the line, one at each end; but let there be a swivel in the middle of the line to keep the dragons from striking together: before you fire the rockets, light the cases on the dragons; and, if care be taken in firing both at the same time, they will meet in the middle of the line, and seem to fight. Then they will run back and return with great violence; which will have a very pleasing effect. The line for these rockets must be very long, or they will strike too hard together.

Chinese Flyers.—Cases for flyers may be made of different sizes, from one to eight ounces: they must be made thick of paper, and eight interior diameters long; they are rolled in the same manner as tourbillons, with a straight pasted edge, and pinched close at one end. The method of filling them is: the case being put in a mould, whose cylinder, or foot, must be flat at top without a nipple, fill it within $\frac{1}{2}$ a diameter of the middle; then ram in $\frac{1}{2}$ a diameter of clay, on that as much composition as before, on which drive $\frac{1}{2}$ a diameter of clay; then pinch the case close, and drive it down flat: after this is done, bore a hole exactly through the centre of the clay in the middle; then in the opposite sides, at both ends, make a vent; and in that side you intend to fire first make a small hole to the composition near the clay in the middle, from which carry a quick-match, covered with a single paper, to the vent at the other end; then, when the charge is burnt on one side, it will, by means of the quick-match, communicate to the charge on the other (which may be of a different sort). The flyers being thus made, put an iron pin, that must be fixed in the work on which they are to be fired, and on which they are to run through the hole in the middle: on the end of this pin must be a nut to keep the flyer from running off. If you would have them turn back again after they are

burnt, make both the vents at the ends on the same side, which will alter its course the contrary way.

Table Rockets are designed merely to shew the truth of driving, and the judgment of a fire-worker, they having no other effect, when fired, than spinning round in the same place where they begin, till they are burnt out, and shewing nothing more than an horizontal circle of fire.

The method of making these rockets is—Have a cone turned out of hard wood $2\frac{1}{2}$ inches diameter, and as much high; round the base of it draw a line; on this line fix four spokes, two inches long each, so as to stand one opposite the other; then fill four nine-inch one-pound cases with any strong composition, within two inches of the top: these cases are made like tourbillons, and must be rammed with the greatest exactness. Your rockets being filled, fix their open ends on the short spokes; then in the side of each case bore a hole near the clay; all these holes, or vents, must be so made that the fire of each case may act the same way; from these vents carry leaders to the top of the cone, and tie them together. When you would fire the rockets, set them on a smooth table, and light the leaders in the middle, and all the cases will fire together, and spin on the point of the cone.

These rockets may be made to rise like tourbillons, by making the cases shorter, and boring four holes in the under side of each at equal distances: this being done, they are called double tourbillons. All the vents in the under side of the cases must be lighted at once; and the sharp point of the cone cut off, at which place make it spherical.

Another Receipt for Rockets.—Take of saltpetre four pounds; brimstone one pound, and charcoal one pound and a half; or by another direction, saltpetre four pounds, brimstone one pound and a half, charcoal twelve ounces, and meal powder two ounces. These proportions vary again according to the size of the rockets; in rockets of four ounces, mealed powder, saltpetre, and charcoal, are used in the proportions of 10, 2, and 1; but in very large rockets the proportions are, saltpetre four, mealed powder and sulphur one each. When stars are wanted, camphor, alcohol, antimony, and other ingredients, are required, according as the stars are to be blue, white, &c. In some cases gold and silver rain is required; then brass dust, steel dust, saw dust, &c. enter into the composition; hence the varieties may be almost indefinite. With respect to colour, sulphur gives a blue, camphor a white or pale colour, saltpetre a whitish yellow, sal-ammoniac a green, antimony a reddish, rosin a copper colour. These materials require preparation before they are fit for use; and before a person can be qualified for the business of fire-work making, he must understand the method of making the moulds, cases, &c. and be acquainted with the instruments used in the art, their dimensions and materials.

Improvement in Fire-Works.—Professor Proust has discovered that nitrate of soda is an economical article in their composition; and that five parts of the nitrate, one of charcoal, and one of sulphur, afford a powder which produces a flame of a beautiful reddish yellow colour.

Of Wheels and other Works.

Single Vertical Wheels.—There are different sorts of vertical wheels; some having their fells of a circular form, others of an hexagon, octagon, or decagon, form, or any number of sides, according to the length of

the cases you design for the wheel: your spokes being fixed in the nave, nail slips of tin, with their edges turned up, so as to form grooves for the cases to lie in, from the end of one spoke to another; then tie your cases in the grooves head to tail, in the same manner as those on the horizontal water-wheel, so that the cases successively taking fire from one another, will keep the wheel in an equal rotation. Two of these wheels are very often fired together, one on each side of a building; and both lighted at the same time, and all the cases filled alike, to make them keep time together; which they will do if made by the following directions. In all the cases of both wheels, except the first, on each wheel drive two or three ladlesful of slow fire, in any part of the cases; but be careful to ram the same quantity in each case, and in the end of one of the cases, on each wheel, you may ram one ladleful of dead-fire composition, which must be very lightly drove; you may also make many changes of fire by this method. Let the hole in the nave of the wheel be lined with brass, and made to turn on a smooth iron spindle. On the end of this spindle let there be a nut, to screw off and on; when you have put the wheel on the spindle, screw on the nut, which will keep the wheel from flying off. Let the mouth of the first case be a little raised. Vertical wheels are made from ten inches to three feet diameter, and the size of the cases must differ accordingly; four-ounce cases will do for wheels of 14 or16 inches diameter, which is the proportion generally used. The best wood for wheels of all sorts is a light and dry beech.

Horizontal Wheels are best when their fells are made circular; in the middle of the top of the nave must be a pintle, turned out of the same piece as the nave, two inches long, and equal in diameter to the bore of one of the cases of the wheel: there must be a hole bored up the centre of the nave, within half an inch of the top of the pintle. The wheel being made, nail at the end of each spoke (of which there should be six or eight) a piece of wood, with a groove cut in it to receive the case. Fix these pieces in such a manner that half the cases may incline upwards and half downwards, and that, when they are tied on, their heads and tails may come very near together; from the tail of one case to the mouth of the other carry a leader, which secure with pasted paper. Besides these pipes, it will be necessary to put a little meal powder inside the pasted paper, to blow off the pipe, that there may be no obstruction to the fire from the cases. By means of these pipes the case will successively take fire, burning one upwards and the other downwards. On the pintle fix a case of the same sort as those on the wheel: this case must be fired by a leader from the mouth of the last case on the wheel, which case must play downwards: instead of a common case in the middle, you may put a case of Chinese fire, long enough to burn as long as two or three of the cases on the wheel. Horizontal wheels are often fired, two at a time, and made to keep time like vertical wheels, only they are made without any slow or dead fire; 10 or 12 inches will be enough for the diameter of wheels with six spokes.

Spiral Wheels are only double horizontal wheels, and made thus: The nave must be about six inches long, and somewhat thicker than the single sort; instead of the pintle at top, make a hole for the case to be fixed in, and two sets of spokes, one set near the top of the nave, and the other near the bottom. At the end of each spoke cut

a groove wherein you tie the cases, there being no fell; the spokes should not be more than $3\frac{1}{2}$ inches long from the nave, so that the wheel may not be more than 8 or 9 inches in diameter; the cases are placed in such a manner, that those at top play down, and those at bottom play up, but let the third or fourth case play horizontally. The case in the middle may begin with any of the others you please: six spokes will be enough for each set, so that the wheel may consist of twelve cases, besides that on the top: the cases six inches each.

Plural Wheels are made to turn horizontally, and to consist of three sets of spokes, placed six at top, six at bottom, and four in the middle, which must be a little shorter than the rest: let the diameter of the wheel be ten inches; the cases must be tied on the ends of the spokes in grooves cut on purpose, or in pieces of wood nailed on the ends of the spokes, with grooves cut in them as usual: in clothing these wheels, make the upper set of cases play obliquely downwards, the bottom set obliquely upwards, and the middle set horizontally. In placing the leaders, you must order it so that the cases may burn thus, viz. first up, then down, then horizontal, and so on with the rest. But another change may be made, by driving in the end of the 8th case two or three ladlefuls of slow fire, to burn till the wheel has stopped its course; then let the other cases be fixed the contrary way, which will make the wheel run back again: for the case at top you may put a small gerbe; and let the cases on the spokes be short, and filled with a strong brilliant charge.

Illuminated Spiral Wheels.—First have a circular horizontal wheel made two feet diameter, with a hole quite through the nave; then take three thin pieces of deal, three feet long each, and $\frac{3}{4}$ of an inch broad each: one end of each of these pieces nail to the fell of the wheel, at an equal distance from one another, and the other end nail to the block with a hole in its bottom, which must be perpendicular with that in the block of the wheel, but not so large. The wheel being thus made, have a hoop planed down very thin and flat; then nail one end of it to the fell of the wheel, and wind it round the three sticks in a spiral line from the wheel to the block at top: on the top of this block fix a case of Chinese fire; on the wheel you may place any number of cases, which must incline downwards, and burn two at a time. If the wheel should consist of ten cases, you may let the illuminations and Chinese fire begin with the second cases. The spindle for this wheel must be a little longer than the cone, and made very smooth at top, on which the upper block is to turn, and the whole weight of the wheel to rest.

Double Spiral Wheel.—For this wheel the block, or nave, must be as long as the height of the worms, or spiral lines, but must be made very thin, and as light as possible. In this block must be fixed several spokes, which must diminish in length, from the wheel to the top, so as not to exceed the surface of a cone of the same height. To the ends of these spokes nail the worms, which must cross each other several times: these worms clothe with illuminations, the same as those on the single wheels; but the horizontal wheel you may clothe as you like. At top of the worm place a case of spur-fire, or an amber light.

Balloon Wheels are made to turn horizontally: they must be made two feet diameter, without any spokes, and very strong, with any number of sides. On the top of a wheel range and fix in pots, three

inches diameter and seven inches high each, as many of these as there are cases on the wheel: near the bottom of each pot make a small vent; into each of these vents carry a leader from the tail of each case; some of the pots load with stars, and some with serpents, crackers, &c. As the wheels turn, the pots will successively be fired, and throw into the air a great variety of fires.

Fruiloni Wheels.—First have a nave made nine inches long, three in diameter: near the bottom of this nave fix eight spokes, with a hole in the end of each, large enough to receive a two or four ounce case: each of these spokes may be 14 inches long from the block. Near the top of this block fix eight more of the same spokes, exactly over the others, but not so long by two inches. As this wheel is to run horizontally, all the cases in the spoke must play obliquely upwards, and all those in the spoke at bottom obliquely downwards. This being done, have a small horizontal wheel made with eight spokes; each five inches long from the block: on the top of this wheel place a case of brilliant fire: all the cases on this wheel must play in an oblique direction downwards, and burn two at a time, and those on the large wheel four at a time; that is, two of those in the top set of spokes, and two of those in the bottom set of spokes.

The four first cases on the large wheel, and the two first on the small, must be fired at the same time, and the brilliant fire at top at the beginning of the last cases. The cases of the wheels may be filled with a grey charge. When these wheels are completed, you must have a strong iron spindle, made four feet six inches long, and fixed perpendicularly on the top of a stand: on this put the large wheel, whose nave must have a hole quite through from the bottom to the top. This hole must be large enough to turn easy round the bottom of the spindle, at which place there must be a shoulder, to keep the wheel from touching the stand: at the top of the spindle put the small wheel, and join it to a large one with a leader, in order that they may be fired both together.

Cascades of Fire.—The top piece of the cascade may be of any length, so as to hold the cases at a little distance from each other; all the cross pieces are fixed horizontally, and supported by brackets; the bottom cross piece should be about one foot six inches broad in the middle, the second one foot, the third nine inches, and the top piece four inches: the cases may be made of any length, but must be filled with a brilliant charge. On the edges of the cross pieces must be nailed bits of wood, with a groove cut in each piece, large enough for a case to lie in. These bits of wood are fixed so as to incline downwards, and that the fire from one tier of cases may play over the other. All the cases being tied fast on, carry leaders from one to the other; and let there be a pipe hung from the mouth of one of the cases, covered at the end with a single paper, which you burn to fire the cascade.

The Fire-Tree.—To make a fire-tree, you must first have a piece of wood six feet long, and three inches square; then at nine inches from the top, make a hole in the front, and in each side; or, instead of holes, you may fix short pegs, to fit the inside of the cases. At nine inches lower, fix three more pegs; at one foot nine inches from thence, fix three pegs; at nine inches lower, fix three pegs; at nine inches from thence, fix three pegs, inclining downwards; but all the other pegs must incline upwards: then at top place a four-inch mortar, loaded with

stars, rains, and crackers. In the middle of this mortar place a case filled with any sort of charge, but let it be fired with the other cases: a brilliant charge will do for all the cases; but the mortar may be made of any diameter, and the tree of any size; and on it any number of cases, provided they are placed in the manner described.

Chinese Fountains.—To make a Chinese fountain, you must have a perpendicular piece of wood seven feet long and $2\frac{1}{2}$ inches square. Sixteen inches from the top, fix on the front a cross-piece one inch thick, and $2\frac{1}{2}$ broad, with the broad side up: below this, fix three more pieces of the same width and thickness, at sixteen inches from each other: let the bottom rail be five feet long, and the others of such a length as to allow the fire-pumps to stand in the middle of the intervals of each other. The pyramid being thus made, fix in the holes made in the bottom rail five fire-pumps, at equal distances; on the 2d rail, place four pumps; on the 3d, three; on the 4th, two; and on the top of the post, one; but place them all to incline a little forwards, that, when they throw out the stars, they may not strike against the cross rails. Having fixed your fire-pumps, clothe them with leaders, so that they may all be fired together.

Of Illuminated Globes with Horizontal Wheels.—The hoops for these globes may be made of wood, tin, or iron wire, about two feet diameter. For a single globe take two hoops, and tie them together, one within the other, at right angles; then have a horizontal wheel made, whose diameter must be a little wider than the globe, and its nave six inches long; on the top of which the globe is fixed, so as to stand three or four inches from the wheel: on this wheel you may put any number of cases, filled with what charge you like; but let two of them burn at a time: they may be placed horizontally, or to incline downwards, just as you choose. Now, when the wheel is clothed, fix on the hoops as many illuminations as will stand within $2\frac{1}{2}$ inches of each other: these you fasten on the hoops with small iron binding wire; and, when they are all on, put on your pipes of communication, which must be so managed as to light them all with the second or third case on the wheel. The spindle on which the globe is to run must go through the block of the wheel, up to the inside of the top of the globe; where must be fixed a bit of brass, or iron, with a hole in it to receive the point of the spindle on which the whole weight of the wheel is to bear, which represents a globe on its spindle. By this method may be made a crown, which is done by having the hoops bent in the form of a crown. Sometimes globes and crowns are ordered so as to stand still, and the wheel only to turn round; but when you would have the globe or crown to stand still, and the wheel to run by itself, the block of the wheel must not be so long, nor the spindle any longer than to just raise the globe a little above the wheel; and the wheel cases and illumination must begin together.

Dodecaedron, so called because it nearly represents a twelve-sided figure, is made thus. First have a ball turned out of some hard wood, fourteen inches diameter: when done, divide its surface into fourteen equal parts, from which bore holes $1\frac{1}{2}$ inch diameter, perpendicular to the centre, so that they may all meet in the middle: then let there be turned in the inside of each hole a female screw; and to all the holes but one, must be made a round spoke five feet long, with four inches of the screw at one end to fit the holes; then in the screw-end of all

the spokes bore a hole, five inches up, which must be bored slanting, so as to come out at one side, a little above the screw ; from which cut a small groove along the spoke, within six inches of the other end, where you make another hole through to the other side of the spoke. In this end fix a spindle, on which put a small wheel of three or four sides, each side six or seven inches long : these sides must have grooves cut in them, large enough to receive a two or four oz. case. When these wheels are clothed, put them on the spindles, and at the end of each spindle put a nut to keep the wheel from falling off. The wheels being thus fixed, carry a pipe from the mouth of the first case on each wheel through the hole in the side of the spoke, and from thence along the groove, and through the other hole, so as to hang out at the screw-end about an inch. The spokes being all prepared in this manner, you must have a post, on which you intend to fire the work, with an iron screw in the top of it, to fit one of the holes in the ball : on the screw fix the ball ; then in the top hole of the ball put a little meal-powder, and some loose quick-match : then screw in all the spokes ; and in one side of the ball bore a hole, in which put a leader, and secure it at the end ; and your work will be ready to be fired. By this leader the powder and match in the centre is fired, which will light the match at the ends of the spokes all at once, whereby all the wheels will be lighted at once. There may be an addition to this piece, by fixing a small globe on each wheel, or one on the top wheel only. A grey charge will be proper for the wheel-cases.

The Yew-Tree of brilliant Fire.—First, let there be an upright piece of wood, four feet long, two inches broad, and one thick : at top of this piece, on the flat side, fix a hoop fourteen inches diameter ; and round its edge and front place illuminations, and in the centre a five-pointed star ; then at $1\frac{1}{2}$ foot from the edge of the hoop, place two cases of brilliant fire, one on each side: these cases should be one foot long each : below these fix two more cases of the same size, and at such a distance, that their mouths may almost meet them at top : then close to the ends of these cases fix two more of the same cases ; and they must stand parallel. The cases being thus fixed, clothe them with leaders ; so that they, with the illuminations and stars at top, may all take fire together.

Stars with Points for regulated Pieces, &c.—These stars are made of different sizes, according to the work for which they are intended : they are made with cases from 1 oz. to 1 lb. but in general with 4 oz. cases, four or five inches long : the cases must be rolled with paste, and twice as thick of paper as a rocket of the same bore. Having rolled a case, pinch one end of it quite close : then drive in half a diameter of clay ; and when the case is dry, fill it with composition, two or three inches to the length of the cases with which it is to burn ; at top of the charge drive some clay ; as the ends of these cases are seldom pinched, they would be liable to take fire. Having filled a case, divide the circumference of it at the pinched end close to the clay into five equal parts ; then bore five holes with a gimblet, about the size of the neck of a common four ounce case, into the composition : from one hole to the other carry a quick-match, and secure it with paper : this paper must be put on in the manner of that on the ends of wheel cases, so that the hollow part, which projects from the end of the case, may serve

to receive a leader from any other work, to give fire to the points of the stars. These stars may be made with any number of points.

Fixed Sun with a Transparent Face.—To make a sun of the best sort, there should be two rows of cases, which will shew a double glory, and make the rays strong and full. The frame, or sun wheel, must be made thus:—Have a circular flat nave made very strong, 12 inches diameter; to this fix six strong flat spokes. On the front of these fix a circular fell, five feet diameter; within which fix another fell, the length of one of the sun cases less in diameter; within this fix a third fell, whose diameter must be less than the second by the length of one case and $\frac{1}{8}$. The wheel being made, divide the fells into so many equal parts as you would have cases (which may be done from 24 to 44): at each division fix a flat iron staple; these staples must be made to fit the cases, to hold them fast on the wheel; let the staples be so placed, that one row of cases may lie in the middle of the intervals of the other.

In the centre of the block of the sun drive a spindle, on which put a small hexagon wheel, whose cases must be filled with the same charge as the cases of the sun: two cases of this wheel must burn at a time, and begin with them on the fells. Having fixed on all the cases, carry pipes of communication from one to the other, and from one side of the sun to the wheel in the middle, and from thence to the other side of the sun. These leaders will hold the wheel steady, while the sun is fixing up, and will also be a sure method of lighting both cases of the wheel together. A sun thus made is called a brilliant sun, because the wood-work is entirely covered with fire from the wheel in the middle, so that there appears nothing but sparks of brilliant fire; but if you would have a transparent face in the centre, you must have one made of pasteboard of any size. The method of making a face is by cutting out the eyes, nose, and mouth, for the sparks of the wheel to appear through; but instead of this face, you may have one painted on oiled paper, or Persian silk, straightened tight on a hoop; which hoop must be supported by 3 or 4 pieces of wire at 6 inches distance from the wheel in the centre, so that the light of it may illuminate the face. By this method you may have, in the front of a sun, *vivat rex* cut in pasteboard, or Apollo painted on silk; but, for a small collection, a sun with a single glory, and a wheel in front, will be most suitable. Half pound cases, filled 10 inches with composition, will be a good size for a sun of 5 feet diameter; but if larger, the cases must be greater in proportion.

Three Vertical Wheels illuminated, which turn on their own Naves upon a horizontal Table.—Let there be a deal table 3 feet in diameter; this table must be fixed horizontally on the top of a post; on this post must be a perpendicular iron spindle, which must come through the centre of the table: then let there be three spokes joined to a triangular flat piece of wood, in the middle of which make a hole to fit easily over the spindle: let there be pieces of wood 4 or 5 inches long each, and 2 inches square, fixed on the under sides of the spokes; in these pieces make holes lengthwise to receive the thin part of the blocks of the wheels, which, when in, are prevented from coming out by a small iron pin being run through the end of each. Fix on three vertical octagon wheels, 18 inches diameter each: the blocks of these wheels must be long enough for 3 or 4 inches to rest on the table; round which part drive a number of sharp points of wire, which must

not project out of the blocks more than one-sixteenth of an inch: the use of these points is, that when the blocks run round, they will stick in the table, and help the wheels forward: if the naves are made of strong wood, one inch will be enough for the diameter of the thin part, which should be made to turn easy in the holes in the pieces. On the front of the wheels make 4 or 5 circles of strong wire, or flat hoops, and tie on them as many illuminations as they will hold at 2 inches from each other: instead of circles you may make spiral lines, clothed with illuminations, at the same distance from each other as those on the hoops. When illuminations are fixed on a spiral line in the front of a wheel, they must be placed a little on the slant, the contrary way that the wheel runs: the cases for these wheels may be filled with any coloured charge, but must burn only one at a time.

The wheels being thus prepared, you must have a globe, crown, or spiral wheel, to put on the spindle in the middle of the table: this spindle should be just long enough to raise the wheel of the globe, crown, or spiral wheel, so high that its fire may play over the 3 vertical wheels: by these means their fires will not be confused, nor will the wheels receive any damage from the fire of each other. In clothing this work, let the leaders be so managed that all the wheels may light together, and the illuminations after two cases of each wheel are burned.

Illuminated Works.

Illuminated works are much admired by the Italians, and indeed are a great addition to a collection of works. In a grand exhibition an illuminated piece should be fired after every 2 or 3 wheels, or fixed pieces of common and brilliant fires; and likewise illuminated works may be made cheap, quick, and easy.

Illuminated Chandelier. To make an illuminated chandelier, you must first have one made of thin wood. The chandelier being made, bore in the front of the branches, and in the body, and also in the crown at top, as many holes for illuminations as they will contain at 3 inches distance from each other: in these holes put illuminations filled with white, blue, or brilliant charge. Having fixed in the port-fires, clothe them with leaders, so that the chandelier and crown may light together. The mouths of the illuminations must project straight from the front.

Illuminated Yew Tree.—First have a tree made of wood, as described above. The middle piece or stem, on which the branches are fixed, must be 8 feet 6 inches high: at the bottom of this piece draw a line at right angles, 2 feet 6 inches long at each side; then at 1 foot 6 inches from the bottom, fix the branches. Set on the 2 top branches parallel to them at bottom: let the length of each of these branches be 1 foot from the stem; then fixed on 5 more branches between, at an equal distance from each other. When the branches are fixed, place illuminating port-fires on the top of each, as many as you choose: behind the top of the stem fasten a gerbe or white fountain, which must be fired at the beginning of the illuminations on the tree.

Flaming Stars with brilliant Wheels.—To make a flaming star, you must first have made a circular piece of strong wood about 1 inch thick and 2 feet diameter: round this block fix 8 points, 2 feet 6 inches long each: 4 of these points must be straight and 4 flaming: these points being joined on very strong, and even with the surface of

the block, nail tin or pasteboard on their edges, from the block to the end of each, where they must be joined: this tin must project in front 8 inches, and be joined where they meet at the block: round the front of the block fix 4 pieces of thick iron wire 8 inches long each, equally distant from each other: this being done, cut a piece of pasteboard round 2 feet diameter, and draw on it a star. Cut out this star, and on the back of it paste oiled paper; then paint each point half red and half yellow lengthwise; but the body of the star must be left open, wherein must run a brilliant wheel made thus: have a light block turned 9 inches long; at each end of it fix 6 spokes; at the end of each spoke put a 2-ounce case of brilliant fire: the length of these cases must be in proportion to the wheel, and the diameter of the wheel, when the cases are on, must be a little less than the diameter of the body of the small star: the cases on the spokes in front must have their mouths incline outwards, and those on the inside spokes must be placed so as to form a vertical circle of fire. When you place your leaders, carry the first pipe from the tail of one of the cases in front to the mouth of one of the inside cases, and from the tail of that to another in front, and so on to all the cases. Your wheel being made, put it on a spindle in the centre of the star; this spindle must have a shoulder at the bottom to keep the wheel at a little distance from the block. This wheel must be kept on the spindle by a nut at the end; having fixed on the wheel, fasten the transparent star to the 4 pieces of wire: when you fire it, you will only see a common horizontal wheel; but when the first case is burnt out, it will fire one of the vertical cases, which will shew the transparent star, and fill the large flames and points with fire: then it will again appear like a common wheel, and so on for 12 charges.

Projected regulated Piece of nine Mutations.

A regulated piece, if well executed, is as curious as any in fireworks: it consists of fixed and moveable pieces on one spindle, representing various figures, which take fire successively one from another without any assistance after lighting the first mutation.

I. Names of the mutations, with the colour of fire and size of the case belonging to each.

First mutation is a hexagon vertical wheel, illuminated in front with small port-fires tied on the spokes: this wheel must be clothed with 2-ounce cases, filled with black charge; the length of these cases is determined by the size of the wheel, but must burn singly.

Second mutation is a fixed piece, called a golden glory, by reason of the cases being filled with spur-fire. The cases must stand perpendicular to the block on which they are fixed, so that when burning, they may represent a glory of fire. This mutation is generally composed of 5 or 7 two-ounce cases.

Third mutation is moveable, and is only an octagon vertical wheel, clothed with 4-ounce cases, filled with brilliant charge: 2 of these cases must burn at a time. In this wheel you may make changes of fire.

Fourth mutation is a fixed sun of brilliant fire, consisting of 12 four-ounce cases: the necks of these cases must be a little larger than those of four-ounce wheel-cases. In this mutation may be made a change of fire, by filling the cases half with brilliant charge, and half with grey.

Fifth mutation is a fixed piece called the porcupine's quills. This piece consists of 12 spokes, standing perpendicular to the block in which they are fixed; on each of these spokes, near the end, must be placed a 4-ounce case of brilliant fire. All these cases must incline either to the right or left, so that they may all play one way.

Sixth mutation is a standing piece called the cross fire. This mutation consists of 8 spokes fixed in a block; near the end of each of those spokes must be tied 2 four-ounce cases of white charge, one across the other, so that the fires from the cases on one spoke may intersect the fire from the cases on the other.

Seventh mutation is a fixed wheel, with two circular fells, on which are placed 16 eight-ounce cases of brilliant fire, in the form of a star. This piece is called a fixed star of wild-fire.

Eighth mutation. This a beautiful piece, called a brilliant star-piece. It consists of 6 spokes, which are strengthened by two fells of a hexagon form at some distance from each other: at the end of each spoke, in the front, is fixed a brilliant star of 5 points; and on each side of every star is placed a four-ounce case of black or grey charge; these cases must be placed with their mouths sideways, so that their fires may cross each other.

Ninth mutation is a wheel-piece. This is composed of 6 long spokes with a hexagon vertical wheel at the end of each; these wheels run on spindles in the front of the spokes; all the wheels are lighted together. Two-ounce cases will do for these wheels, and may be filled with any coloured charge.

II. Proportions of the mutations, with the method of conveying the fire from one to the other, and the distance they stand one from the other on the spindle.

First mutation must be a hexagon vertical wheel 14 inches diameter; on one side of the block, whose diameter is $2\frac{1}{4}$ inches, is fixed a tin barrel. This barrel must be a little less in diameter than the nave: let the length of the barrel and block be 6 inches. Having fixed the cases on the wheel, carry a leader from the tail of the last case into the tin barrel through a hole made on purpose two inches from the block; at the end of this leader let there be about one inch or two of loose match; but take care to secure well the hole wherein the pipe is put to prevent any sparks falling in, which would light the second mutation before its time, and confuse the whole.

Second mutation is made thus: Have a nave turned $2\frac{1}{2}$ inches diameter, and three long; then let half an inch of that end which faces the first wheel be turned so as to fit easy into the tin barrel of the first mutation, which must turn round it without touching. On the other end of the block fix a tin barrel. This barrel must be six inches long, and only half an inch of it to fix on the block. Round the nave fix five spokes, $1\frac{1}{2}$ inches long each; the diameter of the spokes must be equal to a 3 oz. former. On these spokes put five 7 inch 2 oz. cases of spur-fire, and carry leaders from the mouth of one to the other that they may all light together. Then from the mouth of one of the cases carry a leader through a hole bored slantwise in the nave from between the spokes, to the front of the block near the spindle hole: the end of this leader must project out of the hole into the barrel of the first mutation, so that when the pipe which comes from the end of the last

case on the first wheel flashes it may take fire, and light the second mutation. To communicate the fire to the third mutation, bore a hole near the bottom of one of the five cases to the composition, and from thence carry a leader into a hole made in the middle of the barrel: this hole must be covered with pasted paper.

Third mutation may be either an octagon or an hexagon wheel, 20 inches diameter; let the nave be $3\frac{1}{4}$ inches diameter, and $3\frac{1}{2}$ in length; $1\frac{1}{2}$ inch of the front of the nave must be made to fit in the barrel. On the other end of the block fix also a tin barrel. This barrel must be $6\frac{1}{2}$ inches in length, one inch of which must fit over the block. The cases of this wheel must burn two at a time; and from the mouths of the two first cases carry a leader through holes in the nave, into the barrel of the second mutation, after the usual manner: but besides these leaders, let the pipe go across the wheel from one first case to the other; then from the tail of one of the last cases carry a pipe into a hole in the middle of the barrel; at the end of this pipe let there be some loose quick-match.

Fourth and fifth mutations.—These may be described under one head, as their naves are made of one piece, which is 14 inches: first, a block 4 inches diameter, with 10 or 12 short spokes, on which are fixed 11 inch 8-oz. cases: let the front of this block be made to fit easy in the barrel, and clothe the cases so that they may all light together; and let a pipe be carried through a hole in the block into the barrel, in order to receive the fire from the leader brought from the last case on the wheel. The nave of the fifth mutation must be $4\frac{1}{2}$ inches in diameter; in this nave fix 10 or 12 spokes, $1\frac{1}{2}$ foot in length each; these spokes must stand 7 inches distant from the spokes of the fourth mutation; and at the end of each spoke tie a 4-oz. case. All these cases are to be lighted together by a leader brought from the end of one of the cases.

Sixth and seventh mutations.—The blocks of these two mutations are turned out of one piece of wood, whose length is 15 inches. First, a block 5 inches diameter, in which are fixed 8 spokes, each 2 feet 4 inches long: at the end of each spoke tie 2 four-ounce cases. All these cases must be fired at the same time by a pipe brought from the end of one of the cases on the 5th mutation. Let the distance between the spokes, and those in the 5th mutation be 7 inches. The nave of the 7th mutation must be $5\frac{1}{2}$ inches diameter; in this nave fix 8 spokes, and on the front of them 2 circular fells, one of 4 feet 8 inches diameter, and one of 3 feet 11 diameter: on these fells tie 16 eight-ounce or pound cases, and carry leaders from one to the other, so that they may be all fired together. This mutation must be fired by a leader brought from the tail of one of the cases on the 6th mutation.

Eighth and ninth mutations.—The blocks of these may be turned out of one piece, whose length must be 12 inches. The block of the 8th mutation must be 6 inches diameter; and in it must be fixed 6 spokes, each 3 feet in length, strengthened by an hexagon fell within 3 or 4 inches of the ends of the spokes: close to the end of each spoke in the front fix a five-pointed brilliant star; then 7 inches below each star tie 2 ten-inch eight-ounce cases, so that the upper ends of the cases may rest on the fells, and their ends on the spokes. Each of these cases must be placed parallel to the opposite fell.

The ninth mutation must have a block 7 inches diameter. In this block must be screwed 6 spokes, 6 feet long each, with holes and grooves for leaders, as those in the dodecaedron; at the end of each spoke in the front, fix a spindle for a hexagon vertical wheel 10 inches diameter. When these wheels are on, carry a leader from each into the block so that they may all meet; then lead a pipe from the end of one of the cases of the 8th mutation, through a hole bored in the block, to meet the leaders from the vertical wheels, so that they may all be fired together.

The spindles for larger pieces are required to be made very strong, and as exact as possible: for a piece of 9 mutations, let the spindle be at the large end one inch diameter, and continue that thickness as far as the 7th mutation; and thence to the 5th, let its diameter be $\frac{3}{4}$ of an inch; from 5th to the 4th, five-eighths of an inch; from the 4th to the 2d, $\frac{1}{2}$ inch; and from the second to the end, three-eighths of an inch. At the small end must be a nut to keep on the first wheel, and at the thick end must be a large nut, so that the screw part of the spindle being put through a post, and a nut screwed on tight, the spindle will be held fast and steady: but you are to observe, that that part of the spindle on which the moveable pieces are to run, be made long enough for the wheels to run easy without sticking; the fixed pieces being made on different blocks, the leaders must be joined after they are fixed on the spindle. The best method of preventing the fixed mutations from moving on the spindle, is to make that part of the spindle which goes through them square; but as it would be difficult to make square holes through such long blocks as are sometimes required, it will be best to make them thus:—Bore a hole little larger than the diameter of the spindle; and at each end of the block, over the hole, fasten a piece of brass with a square hole in it to fit the spindle.

To make an Horizontal Wheel change to a Vertical Wheel with a Sun in front.

The sudden change of this piece is very pleasing; and gives great surprise to those who are not acquainted with the contrivance. A wheel for this purpose should be about three feet diameter, and its fell circular; on which tie 16 half-pound cases filled with brilliant charge: two of these cases must burn at a time; and on each end of the nave must be a tin barrel of the same construction as those on the regulated piece. The wheel being completed, prepare the post or stand thus:—First have a stand made of any height, about three or four inches square; then saw off from the top a piece two feet long; this piece join again at the place where it was cut, with a hinge on one side, so that it may lift up and down in the front of the stand: then fix on the top of the bottom part of the stand, on each side, a bracket; which brackets must project at right angles with the stand, one foot from the front, for the short piece to rest on. These brackets must be placed a little above the joint of the post, so that when the upper stand falls, it may lie between them at right angles with the bottom stand; which may be done by fixing a piece of wood, one foot long, between the brackets, and even with the top of the bottom stand; then as the brackets rise above the bottom stand, they will form a channel for the short post to lie in, and keep it steady without straining the hinge. On the side of the short post, opposite the hinge, nail a piece of wood,

of such a length, that when the post is perpendicular it may reach about $1\frac{1}{2}$ foot down the long post; to which being tied, it will hold the short stand upright. The stand being thus prepared, in the top of it fix a spindle ten inches long: on this spindle put the wheel; then fix on a brilliant sun with a single glory; the diameter of this sun must be six inches less than that of the wheel. When you fire this piece, light the wheel first, and let it run horizontally till four cases are consumed; then from the end of the fourth case carry a leader into the tin barrel that turns over the end of the stand: this leader must be met by another brought through the top of the post, from a case filled with a strong port-fire charge, and tied to the bottom post, with its mouth facing the packthread which holds up the stand; so that when this case is lighted, it will burn the packthread, and let the wheel fall forward, by which means it will become vertical: then from the last case of the wheel, carry a leader into the barrel next the sun, which will begin as soon as the wheel is burnt out.

Grand Volute, illuminated with a projected Wheel in front.—First have two hoops made of strong iron wire, one of 6 feet diameter, and one of 4 feet 2 inches; these hoops must be joined to scrolls. These scrolls must be made of the same sort of wire as the hoops; on these scrolls tie, with iron-binding wire, as many illuminating port-fires as they will hold, at two inches distance; clothe these port-fires with leaders so that they may all take fire together: then add a circular wheel of four spokes, 3 feet 6 inches diameter; and on its fell tie as many four-ounce cases, head to tail, as will complete the circle, only allowing a sufficient distance between the cases, that the fire may pass free; which may be done by cutting the upper part of the end of each case a little shelving: on each spoke fix a four-ounce case, about three inches from the fell of the wheel: these cases are to burn one at a time, and the first of them to begin with those on the fell, of which four are to burn at a time; so that the wheel will last no longer than one-fourth of the cases on the fell, which in number should be 16 or 20. On the front of the wheel form a spiral line with strong wire, on which tie port-fires, placing them on a slant with their mouths to face the same way as the cases on the wheel: all these port-fires must be fired with the second cases of wheel. Let the spokes of wood be all made to screw into a block in the centre; each of these spokes may be in length about 4 feet 6 inches; in the top of each fix a spindle, and on each spindle put a spiral wheel of eight spokes. The blocks of these wheels must have a hole at top for the centre cases, and the spindle must have nuts screwed on their ends; which nuts should fit in the holes at top of the blocks, so that all the wheels must be put on before you fix in the centre cases. As some of these wheels, by reason of their situation, will not bear on the nut, it will be necessary to have smooth shoulders made on the spindles for the blocks to run on. The cases of these wheels are to burn double; and the method of firing them is by carrying a leader from each down the spokes into the block in the centre, as in the dodecaedron, but the centre case of each wheel must begin with the last two cases as usual. It is to be observed, that the large circular wheel in front must have a tin barrel on its block, into which a pipe must be carried from one of the second cases on the wheel; this pipe being met by another from the large block, in which

the eight spokes are screwed, will fire all the spiral wheels and the illuminating port-fires at the same time. The cases of the projected wheel may be filled with a white charge, and those of the spiral wheels with a grey.

Moon and seven Stars.—Procure a smooth circular board 6 feet diameter: out of the middle of it cut a circular piece 12 or 14 inches diameter; and over the vacancy put white Persian silk, on which paint a moon's face: also sundry stars, each 4 or 5 inches diameter, cut out with five points, and covered with oiled silk: on the front of the large circular board draw a seven-pointed star as large as the circle will allow; then on the lines which form this star, bore holes, wherein fix pointed stars. When this case is to be fired, it must be fixed upon the front of a post, on a spindle with a wheel of brilliant fire behind the face of the moon; so that while the wheel burns, the moon and stars will appear transparent; and when the wheel has burnt out, they will disappear, and the large star in front, which is formed of pointed stars, will begin, being lighted by a pipe of communication from the last case of the vertical wheel behind the moon; this pipe must be managed in the same manner as those in regulated pieces.

Double Cone-Wheel illuminated.—Make a strong decagon wheel, 2 feet 6 inches diameter; then on each side of it fix a cone; these cones are to consist of a number of hoops, supported by three or four pieces of wood in the manner of the spiral wheels. Let the height of each cone be 3 feet 6 inches; and on all the hoops tie port-fires horizontally, with their mouths outwards, and clothe the wheel with eight-ounce cases, all to play horizontally, two at a time: the cones may be fired with the first or second cases. The spindle for this piece must go through both the cones, and rise 3 feet above the point of the cone at top; so that its length will be 10 feet 4 inches from the top of the post in which it is fixed, allowing 4 inches for the thickness of the block of the wheel. The whole weight of the wheel and cones must bear on a shoulder in the spindle, on which the block of the wheel must turn. Near the top of the spindle must be a hole in the front, in which screw a small spindle after the cones are on; then on this small spindle fix a sun composed of sixteen 9-inch 4-ounce cases of brilliant fire, which cases must not be placed on a fell, but only stuck into a block of six inches diameter: then in the front of this sun must be a circular vertical wheel sixteen inches diameter; on the front of this wheel form with iron wire a spiral line, and clothe it with illuminations after the usual method. As this wheel is not to be fired till the cones are burnt out, the method of firing it is thus: Let the hole in the block, at the top of the uppermost cone, be a little larger than the spindle which passes through it; then from the first case of the vertical wheel before the sun, carry a leader down the side of the spindle to the top of the block of the horizontal wheel, on which must be a tin barrel: then this leader being met by another brought from the end of the last case of the horizontal wheel, will give fire to the vertical wheel so soon as the cones are extinguished; but the sun must not be fired til the vertical wheel is quite burnt out.

To make Fire-Pumps.

Cases for fire-pumps are made as those for tourbillons; only they are pasted instead of being rolled dry. Having rolled and dried your cases,

fill them: first put in a little meal-powder, and then a star, on which ram lightly a ladle or two of composition, then a little meal powder, and on that a star, then again composition; and so on till you have filled the case. Stars for fire-pumps should not be round; but must be made either square, or flat and circular, with a hole through the middle: the quantity of powder for throwing the stars must increase as you come near the top of the case: for if much powder be put at the bottom, it will burst the case. The stars must differ in size in this manner: let the star which you put in first be about one-fourth less than the bore of the case; but let the next star be a little larger, and the third star a little larger than the second, and so on: let them increase in diameter till within two of the top of the case, which two must fit in tight. As the loading of fire-pumps is somewhat difficult, it will be necessary to make two or three trials before you depend on their performance. When you fill a number of pumps, take care not to put in each an equal quantity of charge between the stars, so that when they are fired, they may not throw up too many stars together. Cases for fire-pumps should be made very strong, and rolled on four or eight-ounce formers, ten or twelve inches long each.

Vertical Scroll-Wheel.—This wheel may be made of any diameter, but must be constructed in the following manner:—Have a block made of a moderate size, in which fix four flat spokes, and on them fix a flat circular fell of wood; round the front of this fell place port-fires; then on the front of the spokes form a scroll, either with a hoop or strong iron wire; on this scroll tie cases of brilliant fire, in proportion to the wheel, head to tail. When you fire this wheel, light the first case near the fell; then, as the cases fire successively, you will see the circle of fire gradually diminish; but whether the illuminations on the fell begin with the scroll or not is immaterial, that being left entirely to the maker. This wheel may be put in the front of a regulated piece, or fired by itself occasionally.

Pin-Wheels.—First roll some paper pipes, about fourteen inches long each; these pipes must not be made thick of paper, two or three rounds of elephant paper being sufficient. When your pipes are thoroughly dried, you must have a tin tube twelve inches long, to fit easy into the pipes; at one end of this tube fix a small conical cup, which cone is called a funnel; then bend one end of one of the pipes, and put the funnel in at the other end as far as it will reach, and fill the cup with composition: then draw out the funnel by a little at a time, shaking it up and down, and it will fill the pipe as it comes out. Having filled some pipes, have some small blocks made, about one inch diameter, and half an inch thick: round one of these blocks wind and paste a pipe, and to the end of this pipe join another; this must be done by twisting the end of one pipe to a point, and putting it into the end of the other with a little paste: in this manner join four or five pipes, winding them one upon the other so as to form a spiral line. Having wound on your pipes, paste two slips of paper across them to hold them together; besides these slips of paper, the pipes must be pasted together.

There is another method of making these wheels, viz. by winding on the pipes without paste, and sticking them together with sealing-wax at every half turn; so that, when they are fired, the end will fall loose every time the fire passes the wax, by which means the circle of

fire will be considerably increased. The formers for these pipes are made from $1\frac{1}{2}$ to $\frac{4}{16}$ths of an inch diameter; and the composition for them is as follows: Meal powder 8 oz. saltpetre 2 oz. and sulphur 1: among these ingredients may be mixed a little steel filings or the dust of cast iron: this composition should be very dry, and not made too fine, or it will stick in the funnel. These wheels may be fired on a large pin, and held in the hand with safety.

Fire-Globes.—There are two sorts of fire-globes; one with projected cases; the other with the cases concealed, thus: Have a globe made of wood, of any diameter you choose, and divide the surface of it into fourteen equal parts, and at each division bore a hole perpendicular to the centre: these holes must be in proportion to the cases intended to be used; in every hole except one, put a case filled with brilliant or any other charge, and let the mouths of the cases be even with the surface of the globe; then cut in the globe a groove, from the mouth of one case to the other, for leaders which must be carried from case to case, so that they may all be fired together; this done, cover the globe with a single paper, and paint it. These globes may be used to ornament a building.

Fire-globes with projected cases are made thus: Your globe being made with fourteen holes bored in it as usual, fix in every hole except one, a case, and let each case project from the globe two-thirds of its length; then clothe all the cases with leaders, so that they may all take fire at the same time. Fire globes are supported by a pintle, made to fit the hole in which there is no case.

To thread and join Leaders and place them on different Works.

Joining and placing leaders is a very essensial part of fire-works, as it is on the leaders that the performance of all complex works depends; for which reason the method of conducting pipes of communication shall be here explained in as plain a manner as possible. Your works being ready to be clothed, proceed thus: Cut your pipes of a sufficient length to reach from one case to the other; then put in the quick-match, which must always be made to go in very easy; when the match is in, cut it off within about an inch of the end of the pipe, and let it project as much at the other end; then fasten the pipe to the mouth of each case with a pin, and put the loose ends of the match into the mouths of the cases, with a little meal powder: this done to all the cases, paste over the mouth of each two or three bits of paper. The preceding method is used for large cases, and the following for small, and for illuminations: First thread a long pipe; then lay it on the tops of the cases, and cut a bit of the under side, over the mouth of each case, so that the match may appear: then pin the pipe to every other case; but before you put on the pipes, put a little meal powder in the mouth of each case. If the cases thus clothed are port-fires on illuminated works, cover the mouth of each case with a single paper; but if they are choaked cases, situated so that a number of sparks from other works may fall on them before they are fired, secure them with three or four papers, which must be pasted on very smooth, that there may be no creases for the sparks to lodge in, which often set fire to the works before their time. Avoid as much as possible placing the leaders too near, or one across the other so as to touch, as it may happen that the flash of one will fire the other; therefore if your works should be so

formed that the leaders must cross or touch, be sure to make them very strong, and secure at the joints, and at every opening.

When a great length of pipe is required, it must be made by joining several pipes in this manner: Having put on one length of match as many pipes as it will hold, paste paper over every joint; but, if a still greater length is required, more pipes must be joined, by cutting about an inch off one side of each pipe near the end, and laying the quick-match together, and tying them fast with small twine; after which, cover the joining with pasted paper.

Placing Fire-Works to be exhibited.

Nothing adds more to the appearance of fire-works than the placing them properly; though the manner of placing them chiefly depends on the judgment of the maker. The following are the rules generally observed, whether the works are to be fired on a building or on stands: If they are a double set, place one wheel of a sort on each side of the building; and next to each of them, towards the centre, place a fixed piece; then wheels, and so on; leaving a sufficient distance between them for the fire to play from one without burning the other. Having fixed some of your works thus in front, place the rest behind them, in the centre of their intervals. The largest piece, which is generally a regulated or transparent piece, must be placed in the centre of the building, and behind it a sun, which must always stand above all the other works. A little before the building, or stands, place your large gerbes; and at the back of the works fix your marron batteries, *pots des aigrettes, pots des brins, pots de saucissons,* air-balloons, and flights of rockets. The rocket stands may be fixed behind, or anywhere else, so as not to be in the way of the works. Single collections are fired on stands; which stands are made in the same manner as theodolite stands, only the top part must be long or short occasionally; these stands may be fixed up very soon without much trouble.

Order of Firing.

1.	Two signal		rockets
2.	Six sky		
3.	Two honorary		
4.	Four caduceus		
5.	Two	vertical	wheels illuminated
6.		spiral	
7.		transparent stars	
8.	A line rocket of five changes		
9.	Four tourbillons		
10.	Two	horizontal wheels	
11.		air balloons illuminated	
12.		Chinese fountains	
13.		regulating pieces of four mutations each	
14.		pots des aigrettes	
15.	Three large gerbes		
16.	A flight of rockets		
17.	Two	balloon wheels	
18.		cascades of brilliant fire	
19.	Twelve sky-rockets		

20. Two illuminated yew trees
21. Two air-balloons of serpents, and two compound
22. Four tourbillons
23. Two Fruiloni wheels
24. Two illuminated globes with horizontal wheels
25. One pot des saucissons
26. Two plural wheels
27. Marron battery
28. Two chandeliers illuminated
29. Range of pots des brins
30. Twelve sky-rockets
31. Two yew-trees of fire
32. Nest of serpents
33. Two double cones illuminated
34. Regulating piece of seven mutations, viz.
    1. Vertical wheel illuminated
    2. Golden glory
    3. Octagon vertical wheel
    4. Porcupine's quills
    5. Cross fires
    6. Star-piece with brilliant rays
    7. Six vertical wheels
35. Brilliant sun
36. Large flight of rockets

When water-works are to be exhibited, divide them into several sets and fire one set after every fifth or sixth change of land and air works. Observe this rule in firing a double set of works: Always begin with sky rockets, then two moveable pieces, then two fixed pieces, and so on; ending with a large flight of roekets, or a marron battery: if a single collection, fire a fixed piece after every wheel or two, and now and then some air and water works.

Fountain of Sky-rockets.—Procure a perpendicular post, 16 feet high from the ground, and 4 inches square. Let the rail, or cross piece, be 1 foot 6 inches long, 3 inches broad, and 1 thick. The rail at bottom must be 6 feet long, 1 foot broad, and 1 inch thick. The two sides, which serve to supply the rails, are 1 foot broad at bottom, and cut in the front with a regular slope, to 3 inches at top; but their back edges must be parallel with the front of the pots. The breadth of the rail will be determined by the breadth of the sides: all the rails must be fixed at 2 feet distance from each other, and at right angles with the pots. Having placed the rails, bore in the bottom rail 10 holes at equal distances, large enough to receive the stick of a one pound rocket: in the back edge of this rail cut a groove from one end to the other, fit to contain a quick-match; then cut a groove in the top of the rail, from the edge of each hole, into the groove in the back: in the same manner cut in the second rail 8 holes and grooves; in the third rail, 6 holes and grooves; in the fourth rail, 4 holes and grooves; and in the top rail, 2 holes and grooves. Place a rail with holes in it to guide the ends of the rocket-sticks: this rail must be fixed 6 feet from the rail at bottom. The fountain frame being thus made, prepare your rockets thus: Tie round the mouth of each a piece of thin paper, large enough to go twice round, and to project about 1½ inch from the mouth of the rocket, which must be rubbed with wet meal powder; in the mouth of each rocket put a leader, which secure well with the paper that projects from the mouth of the case: these leaders must be carried into the grooves in the back of the rails, in which lay a quick-match from one end to the other, and cover it with pasted paper: holes must be made in the rail at bottom, to receive the ends of the sticks of the rockets, and so on to the fourth rail; so that the sticks of the rockets at top will go through all the rails. The rockets being so prepared,

fix a gerbe, or white flower-pot, on each rail, before the post, with their mouths inclining a little forwards; these gerbes must be lighted all at once. Behind or before each gerbe, fix a case of brilliant or slow fire: these cases must be filled so that they may burn one out after the other, to regulate the fountain; which may be done by carrying a leader from the end of each slow or brilliant fire, into the groove in the back of each rail. Different fixed rockets may be used in these fountains; but it will be best to fill the heads of the rockets on each rail with different sorts of things, in this manner; those at top with crackers, the next with rains, the third with serpents, the fourth with tailed stars, and the last flight with common or brilliant stars.

Palm-Tree.—This piece, though made of common fires and of a simple construction, has a very pleasing effect; owing to the fires intersecting so often, that they resemble the branches of trees. Procure a perpendicular post, of any thickness, so that it is sufficiently strong to hold the cases; let the distance of the arms be 2 feet 6 inches, and let the length of each cross piece be 2 feet; on each end of each fix a five-pointed star: then fix, on pegs made on purpose, 12-inch half-pound cases of brilliant fire. All the cases and stars must be fired at once. This piece should be fixed high from the ground.

Illuminated Pyramid, with Archimedian Screws, a Globe, and vertical Sun,—May be of any height; the space between the rails must be 6 inches, and the rails as thin as possible: in all the rails stick port-fires at 4 inches distance. The Archimedian screws are nothing more than double spiral wheels, with the cases placed on their wheels horizontally instead of obliquely. The vertical sun need not consist of more than 12 rays, to form a single glory. The globe at top must be made in proportion to the pyramid; which being prepared according to the preceding directions, place your leaders so that all the illuminating port-fires, screws, globe, and sun, may take fire together. The pyramid must be supported by the two sides, and by a support brought from a pole, which must be placed two feet from the back of the pyramid, that the wheels may run free.

Rose-piece, and Sun.—A rose-piece may be used for a mutation of a regulated piece, or fired by itself: it makes the best appearance when made large; if its exterior diameter be 6 feet, it will be a good size. Let the exterior fell be made of wood, and supported by 4 wooden spokes: all the other parts, on which the illuminations are fixed, must be made of strong iron wire: on the exterior fell place as many half-pound cases of brilliant charge as you think proper, but the more the better; for the nearer the cases are placed, the stronger will be the rays of the sun: the illuminations should be placed within 3 inches of each other: they must be all fired together, and burn some time before the sun is lighted; which may be done by carrying a leader from the middle of one of the illuminations, to the mouth of one of the sun cases.

Transparent Stars with illuminated Rays.—First make a strong circular back or body of the star, 2 feet diameter, to which you fix the illuminated rays: in the centre of the front of the body fix a spindle, on which put a double triangular wheel, 6 inches diameter, clothed with two ounce cases of brilliant charge: the cases on this wheel must burn but one at a time. Round the edge of the body nail a hoop made of thin wood or tin: this hoop must project in front 5 or 7 inches: in this hoop

cut three or four holes to let out the smoke from the wheel. The star and garter may be cut out of strong pasteboard or tin, made in this manner: Cut a round piece of pasteboard or tin, 2 feet diameter, on which draw a star, and cut it out; then over the vacancy paste Persian silk; paint the letters yellow; 4 of the rays yellow, and 4 red; the cross in the middle may be painted half red and half yellow, or yellow and blue. This transparent star must be fastened to the wooden hoop by a screw, to take off and on; the illuminated rays are made of thin wood, with tin sockets fixed on their sides within 4 inches of each other; in these sockets stick illuminating port-fires; behind the point of each ray fix a half-pound case of grey, black, or Chinese fire. The illuminated rays are to be lighted at the same time as the triangular wheel, or after it is burnt out; which may be done by a tin-barrel being fixed to the wheel, after the manner of those in the regulated pieces. Into this barrel carry a leader from the illuminated rays, through the back of the star; which leader must be met by another, brought from the tail of the last case on the wheel.

Transparent Table Star illuminated.—The centre frame must be 4 feet square; and in this square fix a transparent star. This star may be painted blue, and its rays made as those of the flaming stars desribed before. The wheel for this star may be composed of different coloured fires, with a charge or two of slow fire; the wheels may be clothed with any number of cases, so that the star wheel consist of the same; the illuminating port-fires, which must be placed very near each other on the frames, must be so managed as to burn as long as the wheels, and lighted at the same time.

The regulated Spiral Piece, with a projected Star-wheel illuminated.—This piece may be thus made: Procure a block of 8 inches diameter; in this block screw 6 iron spokes, which must serve for spindles for the spiral wheels: these wheels are made as usual, each 1½ foot diameter, and 3 feet in height: the spindles must be long enough to keep the wheels 4 or 5 inches from one another; at the end of each spindle must be a screw-nut, on which the wheels that hang downwards will run; and on the spindles which stand upwards must be a shoulder, for the blocks of the wheels to run on.

The projected star-wheel must turn on the same spindle on which the large block is fixed; this spindle must be long enough to allow the star wheel to project a little before the spiral wheels: the exterior diameter of the star-wheel must be 3 feet 5 inches. On this wheel fix 3 circles of iron wire, and on them port-fires; on the block place a transparent star, or a large five pointed brilliant star. The cases on this wheel may burn four at once, as it will contain near twice the number of one of the spiral wheels: the cases on the spiral wheels must be placed parallel to their fells, and burn two at a time.

A Figure-piece illuminated with five-pointed Stars.—The construction of this piece is very easy. The vertical wheel in the centre must be 1 foot diameter, and consist of 6 four-ounce cases of different coloured charge, which cases must burn double: on the frames fix five pointed brilliant or blue stars, rammed 4 inches with composition: let the space between each star be 8 inches; at each point fix a gerbe, or case of Chinese fire. When to be fired, let the gerbe, stars, and wheel, be lighted at the same time.

The Star-wheel illuminated.—This beautiful piece hath its exterior

fell made of wood, 3 feet 6 inches, or 4 feet diameter; within this fell, form with iron wire 3 circles, one less than the other, so that the diameter of the least may be about 10 inches: place the port-fires on these fells with their mouths inclining outwards, and the port-fires on the points of the star with their mouths projecting in front: let the exterior fell be clothed with four-ounce cases of grey charge: these cases must burn four at a time, and be lighted at the same time as the illuminations.

Pyramid of Flower-pots.—This curious piece must be made thus: Let the height be 6 feet; and from one rail to the other, 2: on the bottom rail fix five paper mortars, each $3\frac{1}{2}$ inches diameter; these mortars load with serpents, crackers, stars, &c. In the centre of each mortar fix a case of spur-fire: on the second rail fix four mortars, so as to stand exactly in the middle of the intervals of them on the bottom rail; on the third rail place three mortars; on the fourth, 2; and on the top of the post, 1: the bottom rail must be 6 feet long: all the mortars must incline a little forwards, that they may easily discharge; and the spur-fires rammed exactly alike, that the mortars may all be fired at the same time. Having prepared your pyramid according to the preceding directions, carry pipes of communication from one spur-fire to the other.

The illuminating regulating Piece.—Erect flat wooden spokes, each five feet long: at the end of each place a vertical wheel, 10 inches diameter, clothed with 6 four-ounce cases of brilliant fire: these cases must burn but one at a time: on two of the spokes of each wheel place two port-fires, which must be lighted with the first case of the wheel; on each spoke behind the wheels, place six cases of the same size with those on the wheels: these cases must be tied across the spokes with their mouths all one way, and be made to take fire successively one after the other, so that they may assist the whole pieces to turn round.

The diameter of the large wheel must be $2\frac{1}{2}$ feet; and its fell made of wood, which must be fixed to the large spokes: on this wheel place 24 cases of the same sort with those on the small wheels; these cases must burn four at a time; in this wheel make three circles with iron wire, and on them place illuminating port-fires; the star points on the large spokes may be made of thin ash-hoops; the diameter of those points close to the centre-wheel must be 11 inches: on these points place port-fires, at $3\frac{1}{2}$ inches distance one from the other.

Aquatic Fire-Works.

Works that sport in the water are much esteemed by most admirers of fire-works, particularly water-rockets; and, as they seem of a very extraordinary nature to those who are unacquainted with this art, they merit a particular explanation.

Water-rockets, may be made from 4 oz. to 2 lb. If larger, they are too heavy; so that it will be difficult to make them keep above water without a cork float, which must be tied to the neck of the case; but the rockets will not dive so well with as without floats. Cases for these are made in the same manner and proportion as sky-rockets, only a little thicker of paper. When you fill those which are drove solid, put in first one ladleful of slow fire, then two of the proper charge, and on that one or two ladles of sinking charge, then the proper

charge, then the sinking charge again, and so on, till you have filled the case within three diameters; then drive on the composition one ladleful of clay; through which make a small hole to the charge; then fill the case, within $\frac{1}{2}$ a diameter, with corn-powder, on which turn down two or three rounds of the case in the inside; then pinch and tie the end very tight; having filled your rockets, according to the above directions, dip their ends in melted rosin or sealing wax, or else secure them well with grease. When you fire these rockets, throw in six or eight at a time; but, if you would have them all sink, or swim, at the same time, you must drive them with an equal quantity of composition, and fire them all together.

To make Pipes of communication, which may be used under Water.—Pipes for this purpose must be a little thicker of paper than those for land. Having rolled a sufficient number of pipes, and kept them till dry, wash them over with drying oil, and set them to dry; but, when you oil them, leave about $1\frac{1}{2}$ inch at each end dry, for joints: if they were oiled all over, when you come to join them, the paste would not stick where the paper is greasy: after the leaders are joined, and the paste dry, oil the joints. These pipes will lie many hours under water, without receiving any damage.

Horizontal Wheels for the Water.—First get a large wooden bowl without a handle; then have an octagon wheel made of a flat board 18 inches diameter, so that the length of each side will be near seven inches: in all the sides cut a groove for the cases to lie in. This wheel being made, nail it on the top of the bowl; then take four eight-ounce cases, filled with a proper charge, each about 6 inches in length. Now, to clothe the wheel with these cases, get some whitish-brown paper, and cut it into slips four or five inches broad, and seven or eight long: these slips being pasted all over on one side, take one of the cases, and roll one of the slips of paper about $1\frac{1}{2}$ inch on its end, so that there will remain about $2\frac{1}{2}$ inches of the paper hollow from the end of the case: this case tie on one of the sides of the wheel, near the corners of which must be holes bored, through which you put the packthread to tie the cases: having tied on the first case at the neck and end, put a little meal powder in the hollow paper; then paste a slip of paper on the end of another case, the head of which put into the hollow paper on the first, allowing a sufficient distance from the tail of one to the head of the other for the pasted paper to bend without tearing: the second case tie on as you did the first: and so on with the rest, except the last, which must be closed at the end, unless it is to communicate to any thing on the top of the wheel, such as fire-pumps or brilliant fires, fixed in holes cut in the wheel, and fired by the last or second case, as the fancy directs: 6, 8, or any number, may be placed on the top of the wheel, provided they be not too heavy for the bowl.

Before you tie on the cases, cut the upper part of all their ends, except the last, a little shelving, that the fire from one may play over the other, without being obstructed by the case. Wheel-cases have no clay drove in their ends, nor pinched, but are always left open, only the last, or those which are not to lead fire, which must be well secured.

Water Mines.—For these mines you must have a bowl with a wheel on it, made in the same manner as the water-wheel; only in its middle there must be a hole, of the same diameter you design to have the

mine. These mines are tin pots, with strong bottoms, and a little more than two diameters in length: your mine must be fixed in the hole in the wheel, with its bottom resting on the bowl; then loaded with serpents, crackers, stars, small water-rockets, &c. in the same manner as pots of aigrettes: but in their centre fix a case of Chinese fire, or a small gerbe, which must be lighted at the beginning of the last case on the wheel. These wheels are to be clothed as usual.

Fire-globes for the Water.—Bowls for water-globes must be very large, and the wheels on them of a decagon form: on each side of which nail a piece of wood 4 inches long; and on the outside of each piece cut a groove, wide enough to receive about $\frac{1}{4}$ of the thickness of a 4 ounce case: these pieces of wood must be nailed in the middle of each face of the wheel, and fixed in an oblique direction, so that the fire from the cases may incline upwards: the wheel being thus prepared, tie in each groove a 4 ounce case, filled with a grey charge; then carry a leader from the tail of one case to the mouth of the other.—Globes for these wheels are made of two tin hoops, with their edges outwards, fixed one within the other, at right angles. The diameter of these hoops must be somewhat less than that of the wheel. Having made a globe, drive in the centre of a wheel an iron spindle, which must stand perpendicular, and its length 4 or 6 inches more than the diameter of the globe.

This spindle serves for an axis, on which the globe is fixed, which, when done, must stand 4 or 6 inches from the wheel: round one side of each hoop must be soldered little bits of tin, $2\frac{1}{2}$ inches distance from each other; which pieces must be two inches in length each, and only fastened at one end, the other ends being left loose, to turn round the small port-fires, and hold them on; these port-fires must be made of such a length as will last out the cases on the wheel. You are to observe, that there need not be any port-fires at the bottom of the globe within four inches of the spindle; for, if there were, they would have no effect, but only burn the wheel: all the port-fires must be placed perpendicular from the centre of the globe, with their mouths outwards; and must all be clothed with leaders, so as all to take fire with the second case of the wheel; which cases must burn two at a time, one opposite the other. When two cases of a wheel begin together, two will end together; therefore the two opposite end cases must have their ends pinched and secured from fire. The method of firing such wheels is, by carrying a leader from the mouth of one of the first cases to that of the other; which leader being burnt through the middle, will give fire to both at the same time.

Odoriferous Water-Balloons.—These balloons are made in the same manner as air-balloons, but very thin of paper, and in diameter $1\frac{3}{4}$ inch, with a vent of $\frac{1}{2}$ inch diameter. The shells being made, and quite dry, fill them with any of the following compositions, which must be rammed in tight: these balloons must be fired at the vent, and put into a bowl of water. Odoriferous works are generally fired in rooms.

Composition I. Saltpetre, 2 oz. flour of sulphur 1 oz. camphor $\frac{1}{2}$ oz. yellow amber $\frac{1}{2}$ oz. charcoal-dust $\frac{3}{4}$ oz. flour of benjamin or assa odorata $\frac{1}{2}$ oz. all powdered very fine and well mixed.

II. Saltpetre 12 oz. meal-powder 3 oz. frankincense 1 oz. myrrh $\frac{1}{2}$ oz. camphor $\frac{1}{2}$ oz. charcoal 3 oz. all moistened with the oil of spike.

III. Saltpetre 2 oz. sulphur $\frac{1}{2}$ oz. antimony $\frac{1}{2}$ oz. amber $\frac{1}{2}$ oz. cedar raspings $\frac{1}{4}$ oz. all mixed with the oil of roses and a few drops of bergamot.

IV. Saltpetre 4 oz, sulphur 1 oz. saw-dust of juniper $\frac{1}{2}$ oz. saw-dust of cypress 1 oz. camphor $\frac{1}{4}$ oz. myrrh 2 drams, dried rosemary $\frac{1}{4}$ oz. cortex elaterii $\frac{1}{2}$ oz. all moistened a little with the oil of roses. Water rockets may be made with any of the above compositions, with a little alteration, to make them weaker or stronger, according to the size of the cases.

Water-Balloons.—Having made some thin paper shells, of what diameter you please, fill some with the composition for water balloons, and some after this manner: Having made the vent of the shells pretty large, fill them almost full with water rockets, marrons, squibs, &c. Then put in some blowing powder, sufficient to burst the shells; and afterwards fix in the vent a water-rocket, long enough to reach the bottom of the shell, and its neck to project a little out of the vent; this rocket must be open at the end, to fire the powder in the shell, which will burst the shell, and disperse the small rockets, &c. in the water. When you have well secured the large rocket in the vent of the shell, take a cork float with a hole in its middle, which fit over the head of the rocket, and fasten it to the shell: this float must be large enough to keep the balloon above water.

Water squibs are generally made of one ounce serpent cases seven or eight inches long, filled two thirds with charge, and the remainder bounced. The common method of firing them is this: take a water-wheel, with a tin mortar in its centre, which load with squibs after the usual method; but the powder in the mortar must be no more than will just throw the squibs out easily into the water: you may place the cases on the wheel either obliquely or horizontally; and on the top of the wheel, round the mortar, fix six cases of brilliant fire perpendicular to the wheel: these cases must be fired at the beginning of the last case of the wheel, and the mortar at the conclusion of the same.

A Sea fight with small Ships, and to prepare a Fireship for it.—Having procured four or five small ships, of two or three feet in length, (or as many as you design to fight), make a number of small reports, which are to serve for guns. Of these range as many as you please on each side of the upper decks; then at the head and stern of each ship fix a two ounce case, eight inches long, filled with a slow portfire receipt; but take care to place it in such a manner that the fire may fall in the water, and not burn the rigging: in these cases bore holes at unequal distances from one another, but make as many in each case as half the number of reports, so that one case may fire the guns on one side, and the other those on the opposite. The method of firing the guns is, by carrying a leader from the holes in the cases to the reports on the decks; you must make these leaders very small, and be careful in calculating the burning of the slow-fire in the regulating cases, that more than two guns be not fired at a time. When you would have a broadside given, let a leader be carried to a cracker, placed on the outside of the ship; which cracker must be tied loose, or the reports will be too slow: in all the ships put artificial guns at the port-holes.

Having filled and bored holes in two port-fires for regulating the guns in one ship, make all the rest exactly the same; then, when you

begin the engagement, light one ship first, and set it a sailing, and so on with the rest, sending them out singly, which will make them fire regularly, at different times, without confusion; for the time between the firing of each gun will be equal to that of lighting the slow fires.

The fire-ship may be of any size; and need not be very good, for it is always lost in the action. To prepare a ship for this purpose, make a port-fire equal in size with those in the other ships, and place it at the stern; in every port place a large port-fire, filled with a very strong composition, and painted in imitation of a gun, and let them all be fired at once by a leader from the slow fire, within two or three diameters of its bottom; all along both sides, on the top of the upper deck, lay star composition about half an inch thick and one broad, which must be wetted with thin size, then primed with meal powder, and secured from fire by pasting paper over it; in the place where you lay this composition, drive some little tacks with flat heads, to hold it fast to the deck: this must be fired just after the sham guns, and when burning will shew a flame all round the ship: at the head take up the decks, and put in a tin mortar loaded with crackers, which mortar must be fired by a pipe from the end of the slow fire; the firing of this mortar will sink the ship, and make a pretty conclusion. The regulating port-fire of this ship must be lighted at the same time with the first fighting ship.

Having prepared all the ships for fighting, we shall next proceed with the management of them when on the water. At one end of the pond, just under the surface of the water, fix two running blocks, at what distance you choose the ships should fight; and at the other end of the pond, opposite to each of these blocks, under the water, fix a double block; then on the land, by each of the double blocks, place two small windlasses; round one of them turn one end of a small cord, and the other end put through one of the blocks; then carry it through the single one at the opposite end of the pond, and bring it back through the double block again, and round the other windlass: to this cord, near the double block, tie as many small strings as half the number of the ships, at what distance you think proper; but these strings must not be more than two feet each: make fast the loose end of each to a ship, just under her bowsprit; but if tied to the keel, or too near the water, it will overset the ship. Half the ships being thus prepared, near the other double block fix two more windlasses, to which fasten a cord, and to it tie the other half of the ships as before: when you fire the ships, pull in the cord with one of the windlasses, to get all ships together; and when you have set fire to the first, turn that windlass which draws them out, and so on with the rest, till they are all out in the middle of the pond; then, by turning the other windlass, you will draw them back again; by which method you may make them change sides, and tack about backwards and forwards at pleasure. For the fire-ship, fix the blocks and windlasses between the others; so that when she sails out, she will be between the other ships: you must not let this ship advance till the guns at her ports take fire.

To fire Sky-rockets under Water.—You must have stands made as usual, only the rails must be placed flat instead of edgewise, and have holes in them for the rocket-sticks to go through; for, if they were hung upon hooks, the motion of the water would throw them off: the stands being made, if the pond is deep enough, sink them at the sides

so deep, that, when the rockets are in, their heads may just appear above the surface of the water; to the mouth of each rocket fix a leader, which put through the hole with the stick; then a little above the water must be a board, supported by the stand, and placed along one side of the rockets; then the ends of the leaders are turned up through holes made in this board, exactly opposite the rockets. By this means you may fire them singly or all at once. Rockets may be fired by this method in the middle of a pond by a Neptune, a swan, a water-wheel, or any thing else you choose.

To represent Neptune in his Chariot.—To do this to perfection, you must have a Neptune (made of wood, or basket work) as big as life, fixed on a float large enough to bear his weight; on which must be two horses heads and necks, so as to seem swimming. For the wheels of the chariot, there must be two vertical wheels of black fire, and on Neptune's head a horizontal wheel of brilliant fire, with all its cases to play upwards. When this wheel is made, cover it with paper or pasteboard, cut and painted like Neptune's coronet; then let the trident be made without prongs, but instead of them, fix three cases of a weak grey charge, and on each horse's head put an eight ounce case of brilliant fire, and on the mouth of each fix a short case of the same diameter, filled with the white flame receipt, enough to last out all the cases on the wheels: these short cases must be opened at bottom, that they may light the brilliant fires; for the horses' eyes put small port-fires, and in each nostril put a small case filled half with grey charge, and the rest with port-fire composition.

If Neptune is to give fire to any building on the water; at his first setting out, the wheels of the chariot, and that on his head, with the white flames on the horses heads, and the port-fires in their eyes and nostrils, must all be lighted at once; then from the bottom of the white flames carry a leader to the trident. As Neptune is to advance by the help of a block and cord, you must manage it so as not to let him turn about till the brilliant fires on the horses and the trident begin; for it is by the fire from the horses (which plays almost upright) that the building, or work is lighted; which must be thus prepared: From the mouth of the case which is to be first fired, hang some loose quick-match to receive the fire from the horses. When Neptune is only to be shewn by himself, without setting fire to any other works, let the white flames on the horses be very short, and not to last longer than one case of each wheel, and let two cases of each wheel burn at a time.

Swans and Ducks in Water.—If you will have any swans or ducks discharge rockets into the water, they must be made hollow, and of paper, and filled with small water rockets, with some blowing powder to throw them out: but, if this is not done, they may be made of wood, which will last many times. Having made and painted some swans, fix them on floats: then in the places where their eyes should be, bore holes two inches deep, inclining downwards, and wide enough to receive a small port-fire; the port-fire cases for this purpose must be made of brass, two inches long, and filled with a slow bright charge. In the middle of one of these cases make a little hole; then put the port-fire in the eye-hole of the swan, leaving about half an inch to project out; and in the other eye put another port-fire, with a hole made in it: then in the neck of the swan, within two inches of one of the eyes, bore a hole slantwise, to meet that in the port-fire; in this hole

put a leader, and carry it to a water-rocket, that must be fixed under the tail with its mouth upwards. On the top of the head place two one-ounce cases, four inches long each, drove with brilliant fire; one of these cases must incline forwards, and the other backwards: these must be lighted at the same time as the water-rocket; to do which, bore a hole between them in the top of the swan's head, down to the hole in the port-fire, to which carry a leader: if the swan is filled with rockets, which must be fired by a pipe from the end of the water-rocket under the tail. When you set the swan a swimming, light the two eyes.

Water Fire-Fountains.—To make a fire-fountain, you must first have a float made of wood, three feet diameter; then in the middle fix a round perpendicular post, four feet high, and two inches diameter; round this post fix three circular wheels made of thin wood, without any spokes. The largest of these wheels must be placed within two or three inches of the float, and must be nearly of the same diameter.

The second wheel must be 2 feet 2 inches diameter, and fixed at 2 feet distance from the first. The third wheel must be 1 foot 4 inches diameter, and fixed within six inches of the top of the post: the wheels being fixed, take 18 four or eight oz. cases of brilliant fire, and place them round the first wheel with their mouths outwards, and inclining downwards; on the second wheel place 13 cases of the same, and in the same manner as those on the first; on the third, place 8 more of these case, in the same manner as before; and on the top of the post fix a gerbe; then clothe all the cases with leaders, so that both they and the gerbe may take fire at the same time. Before you fire this work, try it in the water to see if the float is properly made, so as to keep the fountain upright.

CHAP. XXI.

AEROSTATION AND AIR-BALLOONS,

We have already mentioned the theory of air-balloons, in our essay on hydrostatics, but the subject is too curious and important to be so easily dismissed. We proceed then to observe, that the air-balloon consists merely of a bag filled with air so light, that it together with the bag, forms a mass which is specifically lighter than the common atmosphere. A cubic foot of common air is found to weigh above 554 grains, and to be expanded by every degree of heat marked on Fahrenheit's thermometers about one fiftieth part of the whole. By heating a quantity of air, therefore, to 200 degrees of Fahrenheit, you will just double its bulk, when the thermometer stands at 54 in the open air; and in the same proportion you will diminish its weights. And if such a quantity of this hot air be inclosed in a bag that the excess of the weight of an equal bulk of common air weighs more than the bag with the air contained in it, both the bag and the air will rise into the atmosphere, and continue to do so till they arrive at a place where the

external air is naturally so much rarefied that the weight becomes equal, and the whole will float.

The power with which hot air is impelled upwards may be shewn by the following experiment: Roll up a sheet of paper in a conical form, and by thrusting a pin into it near the apex, prevent it from unrolling; fasten it then by its apex, under one of the scales of a balance, by means of a thread, and having properly counterpoised it by weights put into the opposite scale, apply the flame of a candle underneath, and you will instantly see the cone rise: and it will not be brought into equilibrium with the other, but by a much greater weight than those who have not seen the experiment would believe.

If the magnitude of a balloon be overrated, its power of ascension, or the difference between the weights of the included air, and an equal bulk of common air, will be augmented in the same proportion. For its thickness being supposed the same, it is as the surface it covers, or only as the square of the diameter. This is the reason why balloons cannot be made to ascend if under a given magnitude, when composed of cloth or materials of the same thickness.

The romances of almost every nation have recorded instances of persons being carried through the air, both by the agency of spirits and by mechanical inventions; but, till the time of the celebrated lord Bacon, no rational principle appears ever to have been thought of by which this might be accomplished. Before that time, indeed, friar Bacon had written upon the subject; and many had been of opinion, that, by means of artificial wings, fixed to the arms or legs, a man might fly as well as a bird: but these opinions were thoroughly refuted by Borelli, in his treatise *De Motu Animalium*, where, from a comparison between the power of the muscles which move the wings of a bird, and those which move the arms of a man, he demonstrates that the latter are utterly insufficient to strike the air with such force as to raise him from the ground. It cannot be denied, however, that wings of this kind, if properly constructed, and dexterously managed, might be sufficient to break the fall of a human body from an high place, so that some adventurers in this way might possibly come off with safety; though by far the greatest number of those who have rashly adopted such schemes have either lost their lives or limbs in the attempt.

In the year 1672, bishop Wilkins published a treatise, intitled, "The Discovery of the New World;" in which he mentions, though in a very indistinct and confused manner, the two principles on which the air is navigable; quoting, from Albertus de Saxonia and Francis Mendoca, "that the air is in some part of it navigable; and upon this static principle, any brass or iron vessel (suppose a kettle), whose substance is much heavier than that of water, yet being filled with the lighter air, it will swim upon it and not sink. So suppose a cup or wooden vessel upon the outward borders of this elementary air, the capacity of it being filled with fire, or rather ethereal air, it must necessarily, upon the same ground, remain swimming there, and of itself can no more fall than an empty ship can sink." This idea, however, he did not by any means pursue, but rested his hopes entirely upon mechanical motions, to be accomplished by the mere strength of a man, or by springs, &c. and which have been demonstrated incapable of answering any useful purpose.

The only person who brought this scheme of flying to any kind of rational principle was the Jesuit Francis Lana, contemporary with bishop Wilkins. He, being acquainted with the real weight of the atmosphere, justly concluded, that, if a globular vessel were exhausted of air, it would weigh less than before; and, considering that the solid contents of vessels increase in much greater proportion than their surfaces, he supposes that a metalline vessel might be made so large, that, when emptied of its air, it would be able not only to raise itself in the atmosphere, but to carry up passengers along with it; and he made a number of calculations necessary for putting the project in execution. But, though the theory was here unexceptionable, the means proposed were certainly insufficient to accomplish the end: for a vessel of copper, made so thin as was necessary to make it float in the atmosphere, would be utterly unable to resist the external pressure; which being demonstrated by those skilled in mechanics, no attempt was made on that principle.

In the year 1709, however, as we were informed by a letter published in France in 1784, a Portuguese projector, friar Gusman, applied to the king for encouragement to his invention of a flying machine. The principle on which this was constructed, if indeed it had any principle, seems to have been that of the paper kite. The machine was constructed in form of a bird, and contained several tubes through which the wind was to pass, in order to fill a kind of sails, which were to elevate it; and when the wind was deficient, the same effect was to be performed by means of bellows concealed within the body of the machine. The ascent was also to be promoted by the electric attraction of pieces of amber placed in the top, and by two spheres inclosing magnets in the same situation.

These childish inventions shew the low state of science at that time in Portugal, especially as the king, in order to encourage him to farther exertions in such a useful invention, granted him the first vacant place in his college of Barcelos or Santarem, with the first professorship in the university of Coimbra, and an annual pension of 600,000 reis during his life. Of this De Gusman it is also related, that, in the year 1736, he made a wicker basket of about seven or eight feet diameter, and covered it with paper, which raised itself about 200 feet in the air, and the effect was generally attributed to witchcraft.

In the year 1766, Mr. Henry Cavendish ascertained the weight and other properties of inflammable air, determining it to be at least seven times lighter than common air. Soon after which, it occurred to Dr. Black, that, perhaps a thin bag filled with inflammable air might be buoyed up by the common atmosphere; and he thought of having the allantois of a calf prepared for this purpose: but his other avocations prevented him from prosecuting the experiment. The same thought occurred some years afterwards to Mr. Cavallo; and he has the honour of being the first who made experiments on the subject. He first tried bladders; but the thinnest of these, however well scraped and prepared, were found too heavy. He then tried Chinese paper; but that proved so permeable, that the vapour passed through it like water through a sieve. His experiments, therefore, made in the year 1782, proceeded no farther than blowing up soap-bubbles with inflammable air, which ascended rapidly to the ceiling, and broke against it.

But, while the discovery of the art of aerostation seemed thus on the point of being made in Britain, it was all at once announced in France,

and that from a quarter whence nothing of the kind was to have been expected. Two brothers, Stephen and John Montgolfier, natives of Annonay, and masters of a considerable paper-manufactory there, had turned their thoughts towards this project as early as the middle of the year 1782. The idea was first suggested by the natural ascent of the smoke and clouds in the atmosphere; and their design was to form an artificial cloud, by inclosing the smoke in a bag, and making it carry up the covering along with it. Towards the middle of November that year, the experiment was made at Avignon, with a fine silk bag of a parallelopipid shape. By applying burning paper to the lower aperture, the air was rarefied, and the bag ascended in the atmosphere, and struck rapidly against the ceiling. On repeating the experiment in the open air, it rose to the height of about seventy feet.

An experiment on a more enlarged scale was now projected; and a new machine, containing about 650 cubic feet, was made, which broke the cords that confined it, and rose to the height of about 600 feet. Another of thirty-five feet in diameter rose about 1000 feet high, and fell to the ground three quarters of a mile from the place where it ascended. A public exhibition was next made on the fifth of June 1783, at Annonay, where a vast number of spectators assembled. An immense bag of linen, lined with paper, and containing upwards of 23,000 cubic feet, was found to have a power of lifting about 500lbs. including its own weight. The operation was begun by burning chopped straw and wool under the aperture of the machine, which immediately began to swell; and after being set at liberty ascended into the atmosphere. In ten minutes it had ascended 6000 feet; and, when its force was exhausted, it fell to the ground at the distance of 7668 feet from the place whence it set out.

Soon after this one of the brothers arrived at Paris, where he was invited by the academy of sciences to repeat his experiments at their expence. In consequence of this invitation, he constructed, in a garden in the fauxbourg of St. Germain, a large balloon of an elliptical form. In a preliminary experiment, this machine lifted up from the ground eight persons who held it, and would have carried them all off if more had not immediately come to their assistance. Next day the experiment was repeated in presence of the members of the academy; the machine was filled by the combustion of fifty pounds of straw made up in small bundles, upon which about twelve pounds of chopped wool were thrown at intervals. The usual success attended this exhibition. The machine soon swelled; endeavoured to ascend; and immediately after sustained itself in the air, together with the charge of between 400 and 500 pounds weight. It was evident that it would have ascended to a great height; but, as it was designed to repeat the experiment before the king and royal family at Versailles, the cords by which it was tied down were not cut. But, in consequence of a violent rain and wind which happened at this time, the machine was so far damaged, that it became necessary to prepare a new one for the time that it had been determined to honour the experiment with the royal presence; and such expedition was used, that this vast machine, of near sixty feet in height, and forty-three in diameter, was made, painted with water-colours both within and without, and finely decorated, in no more than four days and four nights. Along with this machine was sent a wicker cage, containing a sheep, a cock, and a duck, which were the first animals ever sent through

the atmosphere. The full success of the experiment was prevented by a violent gust of wind, which tore the cloth in two places near the top before it ascended. However, it rose to the height of 1440 feet; and, after remaining in the air about eight minutes, fell to the ground at the distance of 10,200 feet from the place of its setting out. The animals were not in the least hurt.

The great power of these aerostatic machines, and their very gradual descent in falling to the ground, had originally shewed that they were capable of transporting people through the air with all imaginable safety; and this was further confirmed by the experiment already mentioned. As M. Montgolfier, therefore, proposed to make a new aerostatic machine of a firmer and better construction than the former, M. Pilatre de Rozier offered himself to be the first aerial adventurer.

This new machine was constructed in a garden in the fauxbourg of St. Antoine. It was of an oval shape, about forty-eight in diameter, and seventy-four in height; elegantly painted on the outside with the signs of the zodiac, cyphers of the king's name, and other ornaments. A proper gallery, grate, &c. were appended in the manner afterwards described; so that it was easy for the person who ascended to supply the fire with fuel, and thus keep up the machine as long as he pleased. The weight of the whole apparatus was upwards of 1600lbs. The experiment was peformed on the 15th of October 1783. M. Pilatre having placed himself in the gallery, the machine was inflated, and permitted to ascend to the height of eighty-four feet, where he kept it afloat for about four minutes and a half; after which it descended very gently: and such was its tendency to ascend, that it rebounded to a considerable height after touching the ground. Two days after, he repeated the experiment with the same success as before; but, the wind being strong, the machine did not sustain itself so well as formerly. On repeating the experiment in calmer weather, he ascended to the height of 210 feet. His next ascent was 262 feet; and, in the descent, a gust of wind having blown the machine over some large trees of an adjoining garden, M. Pilatre suddenly extricated himself from so dangerous a situation, by throwing straw and chopped wool on the fire, which raised him at once to a sufficient height. On descending again, he once more raised himself to a proper height by throwing straw on the fire. Some time after, he ascended in company with M. Girond de Vilette to the height of 330 feet; hovering over Paris at least nine minutes in sight of all the inhabitants, and the machine keeping all the while perfectly steady.

These experiments had shewn, that the aerostatic machines might be raised or lowered at the pleasure of the persons who ascended: they had likewise discovered, that the keeping them fast with the ropes was no advantage; but, on the contrary, this was attended with inconvenience and hazard. On the 21st of November 1783, therefore, M. Pilatre determined to undertake an aerial voyage in which the machine should be fully set at liberty. Every thing being got in readiness, the balloon was filled in a few minutes; and M. Pilatre placed himself in the gallery, counterpoised by the marquis d'Arlandes, who occupied the other side. It was intended to make some preliminary experiments on the ascending power of the machine: but the violence of the wind prevented this from being done, and even damaged the balloon essentially; so that it would have been entirely destroyed had not timely assistance been given. The extraordinary exertions of the workmen, however, repaired it again in

two hours, and the adventurers set out. They met with no inconvenience during their voyage, which lasted about twenty-five minutes; during which time they had passed over the space of above five miles. From the account given by the marquis d'Arlandes it appears, that they met with several different currents of air; the effect of which was, to give a very sensible shock to the machine, and the direction of the motion seemed to be from the upper part downwards. It appears also, that they were in some danger of having the balloon burnt altogether; as the marquis observed several round holes made by the fire in the lower part of it, which alarmed him considerably, and indeed not without reason. However, the progress of the fire was easily stopped by the application of a wet sponge, and all appearance of danger ceased in a very short time.

This voyage of M. Pilatre and the marquis d'Arlandes may be said to conclude the history of those aerostatic machines which are elevated by means of fire; for, though many other attempts have been made upon the same principle, most of them have either proved unsuccessful, or were of little consequence. They therefore gave place to the other kind, filled with inflammable air; which, by reason of its smaller specific gravity, is both more manageable, and capable of performing voyages of greater length, as it does not require to be supplied with fuel like the others. This was invented in a very short time after the discovery had been made by M. Montgolfier. This gentleman had indeed designed to keep his method in some degree a secret from the world; but, as it could not be concealed, that a bag filled with any kind of fluid lighter than the common atmosphere would rise in it, inflammable air was naturally thought of as a proper succedaneum for the rarefied air of M. Montgolfier. The first experiment was made by two brothers, Messrs. Roberts, and M. Charles, a professor of experimental philosophy. The bag which contained the gas was composed of lute-string, varnished over with a solution of the elastic gum called *caoutchouc;* and that with which they made their first essay was only about thirteen English feet in diameter. Many difficulties occurred in filling it with the inflammable air, chiefly owing to their ignorance of the proper apparatus; insomuch, that, after a whole day's labour from nine in the morning, they had got the balloon only one third part full. Next morning they were surprised to find that it had fully inflated of itself during the night: but, upon inquiry, it was found, that they had inadvertently left open a stop-cock connected with the balloon, by which the common air, gaining access, had mixed itself with the inflammable air; forming a compound still lighter than the common atmosphere, but not sufficiently light to answer the purposes of aerostation. Thus they were obliged to renew their operation; and, by six o'clock in the evening of the next day, they found the machine considerably lighter than the common air; and, in an hour after, it made a considerable effort to ascend. The public exhibition, however, had been announced only for the third day after; so that the balloon was allowed to remain in an inflated state for a whole day; during which they found it had lost a power of ascent equal to about three pounds, being one-seventh part of the whole. When it was at last set at liberty, after having been well filled with inflammable air, it was thirty-five pounds lighter than an equal bulk of common air. It remained in the atmosphere only three quarters of an hour, during which it had traversed fifteen miles. Its sudden descent was supposed to have

been owing to a rupture which had taken place when it ascended into the higher regions of the atmosphere.

The success of this experiment, and the aerial voyage made by Messrs. Rozier and Arlandes, naturally suggested the idea of undertaking something of the same kind with a balloon filled with inflammable air. The machine used on this occasion was formed of gores of silk, covered over with a varnish made of *caoutchouc*, of a spherical figure, and measuring twenty-seven feet and a half in diameter. A net was spread over the upper hemisphere, and was fastened to an hoop which passed round the middle of the balloon. To this a sort of car, or rather boat, was suspended by ropes, in such a manner as to hang a few feet below the lower part of the balloon; and, in order to prevent the bursting of the machine, a valve was placed in it; by opening of which some of the inflammable air might be occasionally let out. A long silken pipe communicated with the balloon, by means of which it was filled. The boat was made of basket-work, covered with painted linen, and beautifully ornamented; being eight feet long, four broad, and three and a half deep; its weight 130 pounds. At this time, however, as at the former, they met with great difficulties in filling the machine with inflammable air, owing to their ignorance of the most proper apparatus. But at last, all obstacles being removed, the two adventurers took their seats at three quarters after one in the afternoon of the 1st of December 1793. Persons skilled in the mathematics were conveniently stationed with proper instruments to calculate the height, velocity, &c. of the balloon. The weight of the whole apparatus, including that of the two adventurers, was found to be $604\frac{1}{2}$ pounds, and the power of ascent when they set out was twenty pounds; so that the whole difference betwixt the weight of this balloon and an equal bulk of common air was 624 pounds. But the weight of common atmosphere displaced by the inflammable gas was calculated to be 771 pounds, so that there remains 147 for the weight of the latter; and this calculation makes it only five times and a quarter lighter than common air.

At the time the balloon left the ground, the thermometer stood at 9° of Fahrenheit's scale, and the quicksilver in the barometer at 30.18 inches; and, by means of the power of ascent with which they left the ground, the balloon rose till the mercury fell to twenty-seven inches, from which they calculated their height to be about 600 yards. By throwing out ballast occasionally as they found the machine descending by the escape of some of the inflammable air, they found it practicable to keep at pretty near the same distance from the earth during the rest of their voyage; the quicksilver fluctuating between 27.0 and 27.65 inches, and the thermometer between 53° and 57°, the whole time. They continued in the air for the space of an hour and three quarters, when they alighted at the distance of twenty-seven miles from Paris; having suffered no inconvenience during their voyage, nor experienced any contrary currents of air, as had been felt by Messrs. Pilatre and Arlandes. As the balloon still retained a great quantity of inflammable gas, M. Charles determined to take another voyage by himself. M. Robert accordingly got out of the boat, which was thus lightened by 130 pounds, and of consequence the aerostatic machine now had nearly as much power of ascent. Thus he was carried up with such velocity, that in twenty minutes he was almost 9000 feet high, and entirely out of sight of terrestrial objects. At the moment of his parting with the ground,

the globe had been rather flaccid; but it soon began to swell, and the inflammable air escaped from it in great quantity through the silken tube. He also frequently drew the valve, that it might be the more freely emitted, and the balloon effectually prevented from bursting. The inflammable gas, being considerably warmer than the external air, diffused itself all round, and was felt like a warm atmosphere: but in ten minutes the thermometer indicated a variation of temperature as great as that between the warmth of spring and the ordinary cold of winter. His fingers were benumbed by the cold, and he felt a violent pain in his right ear and jaw, which he ascribed to the dilatation of the air in these organs, as well as to the external cold. The beauty of the prospect which he now enjoyed, however, made amends for these inconveniences. At his departure the sun was set on the valleys; but the height to which M. Charles was got in the atmosphere rendered him again visible, though only for a short time. He saw, for a few seconds, vapours rising from the valleys and rivers. The clouds seemed to ascend from the earth, and collect one upon the other, still preserving their usual form; only their colour was grey and monotonous for want of sufficient light in the atmosphere. By the light of the moon he perceived that the machine was turning round with him in the air; and he observed that there were contrary currents which brought him back again. He observed also, with surprise, the effects of the wind, and that the streamers of his banners pointed upwards; which, he says, could not be the effect either of his ascent or descent, as he was moving horizontally at the time. At last, recollecting his promise of returning to his friends in half an hour, he pulled the valve, and accelerated his descent. When within 200 feet of the earth, he threw out two or three pounds of ballast, which rendered the balloon again stationary; but, in a little time afterwards, he gently alighted in a field about three miles distant from the place whence he set out; though, by making allowances for all the turnings and windings of the voyage, he supposes that he had gone through nine miles at least. By the calculations of M. de Maunier, he rose at this time not less than 10,500 feet high; a height somewhat greater than that of Mount Ætna. A small balloon, which had been sent off before the two brothers set out on their voyage, took a direction opposite to that of the large one, having met with an opposite current of air, probably at a much greater height.

The subsequent aerial voyages differ so little from that just now related, that any particular description of them seems to be superfluous. It had occurred to M. Charles, however, in his last flight, that there might be a possibility of directing the machine in the atmosphere; and this was soon attempted by M. Jean Pierre Blanchard, a gentleman who had, for several years before, amused himself with endeavours to fly by mechanical means, though he had never succeeded in the undertaking. As soon as the discovery of the aerostatic machines was announced, however, he resolved to add the wings of his former machine to a balloon, and made no doubt that it would then be in his power to direct himself through the air at pleasure. In his first attempt he was frustrated by the impetuosity of a young gentleman, who insisted, right or wrong, on ascending along with him. In the scuffle which ensued on this occasion, the wings and other apparatus were entirely destroyed; so that M. Blanchard was obliged to commit himself to the direction of the wind: and in another attempt it was found, that all the strength he

could apply to the wings was scarcely sufficient to counteract the impression of the wind in any degree. In his voyage, he found his balloon, at a certain period, acted upon by two contrary winds; but, on throwing out four pounds of ballast, he ascended to a place where he met with the same current he had at setting out from the earth. His account of the sensations he felt during this voyage was somewhat different from that of M. Charles; having, in one part of it, found the atmosphere very warm, in another cold; and having once found himself very hungry, and at another time almost overcome by a propensity to sleep. The height to which he rose, as measured by several observations with mathematical instruments, was thought to be very little less than 10,000 feet; and he remained in the atmosphere an hour and a quarter.

The attempts of M. Blanchard to direct his machine through the atmosphere were repeated in the month of April 1784, by Messrs. Morveau and Bertrand, at Dijon, who raised themselves in an inflammable air balloon to the height, as it was thought, of 13,000 feet; passing through a space of eighteen miles in an hour and twenty-five minutes. M. Morveau had prepared a kind of oars for directing the machine through the air; but they were damaged by a gust of wind, so that only two of them remained serviceable; by working these, however, they were able to produce a sensible effect on the motion of the machine.

In a third aerial voyage performed by Mr. Blanchard, he seemed to produce some effect by the agitation of his wings, both in ascending, descending, moving sideways, and even in some measure against the wind; however, this is supposed, with some probability, to have been a mistake, as, in all his succeeding voyages, the effects of his machinery could not be perceived.

The success of Messrs. Charles and Robert in their former experiments encouraged them soon to repeat them, with the addition of some machinery to direct their course. Having enlarged their former balloon to an oblong spheriod, forty-six feet and three quarters long and twenty-seven and a half in diameter, they made its float with its longest part parallel to the horizon. The wings were made in the shape of an umbrella without the handle, to the top of which a stick was fastened parallel to the aperture of the umbrella. Five of these were disposed round the boat, which was near seventeen feet in length. The balloon was filled in three hours, and, with the addition of 450 pounds of ballast, remained *in equilibrio* with the atmosphere. About noon, on the 19th of September 1784, they began to ascend very gently in consequence of throwing out twenty-four pounds of ballast, but were soon obliged to throw out eight pounds more in order to avoid running against some trees. Thus they rose to the height of 1400 feet, when they perceived some thunder-clouds near the horizon. On this they ascended and descended, to avoid the danger, as the wind blew directly towards the threatening clouds; but, from the height of 600 feet to that of 4200 above the surface of the earth, the current was quite uniform and in one direction. During their voyage they lost one of their oars; but found, that by means of those which remained they considerably accelerated their course. From the account of their voyage, it should seem that they had passed safely through the thunder-clouds; as we are informed, that, about forty minutes after three, they heard a loud clap of thunder; and, three minutes after, another much louder; at which time the ther-

mometer sunk from 77° to 59°. This sudden cold, occasioned by the approach of the clouds, condensed the inflammable air so that the balloon descended very low, and they were obliged to throw out forty pounds of ballast; yet, on examining the heat of the air within the balloon, they found it to be 104°, when that of the external atmosphere was only 63°. When they had got so high that the mercury in the barometer stood only at 23.94 inches, they found themselves becalmed; so that the machine did not go even at the rate of two feet in a second, though it had before gone at the rate of twenty-four feet in a second. On this they determined to try the effect of their oars to the utmost; and, by working them for thirty-five minutes, and, marking the shadow of the balloon on the ground, they found, in that time, that they had described the segment of an ellipsis whose longest diameter was 6000 feet. After they had travelled about 150 miles, they descended, only on account of the approach of night, having still 200 pounds of ballast left.

Their conclusion, with regard to the effect of their wings, is as follows:—"Those experiments shew, that far from going against the wind, as is said by some persons to be possible in a certain manner, and some aeronauts pretend to have actually done, we only obtained, by means of two oars, a deviation of twenty-two degrees: it is certain, however, that, if we could have used our four oars, we might have deviated about forty degrees from the direction of the wind, and, as our machine would have been capable of carrying seven persons, it would have been easy for five persons to have gone, and to have put in action eight oars, by means of which a deviation of about eighty degrees would have been obtained.

"We had already observed (say they), that, if we did not deviate more than twenty-two degrees, it was because the wind carried us at the rate of twenty-four miles an hour; and it is natural to judge, that, if the wind had been twice as strong as it was, we should not have deviated more than one-half of what we actually did; and, on the contrary, if the wind had been only half as strong, our deviation would have been proportionably greater.

Having thus related all that has been done with regard to the conducting of aerostatic machines through the atmosphere, we shall now relate the attempts that have been made to lessen their expence, by falling upon some contrivance to ascend without throwing out ballast, and to descend without losing any of the inflammable air. The first attempt of this kind was made by the duke de Chartres; who, on the 15th of July 1784, ascended with the two brothers, Charles and Robert, from the park of St. Cloud. The balloon was of an oblong form, made to ascend with its longest diameter horizontally, and measured fifty-five feet in length and twenty-four in breadth. It contained within it a smaller balloon which was filled with common atmospheric air; by blowing into which with a pair of bellows, and thus throwing in a considerable quantity of common air, it was supposed that the machine would become sufficiently heavy to descend, especially as, by the inflation of the internal bag, the inflammable air in the external one would be condensed into a smaller space, and thus become specifically heavier. The voyage, however, was attended with such circumstances as rendered it impossible to know what would have been the event of the scheme. The power of ascent with which they set out seems to have

been very great; as, in three minutes after parting with the ground, they were lost in the clouds, and involved in such a dense vapour that they could see neither the sky nor the earth. In this situation they seemed to be attacked by a whirlwind, which, besides turning the balloon three times round from right to left, shocked and beat it so about, that they were rendered incapable of using any of the means proposed for directing their course, and the silk stuff of which the helm had been composed was even torn away. No scene can be conceived more terrible than that in which they were now involved. An immense ocean of shapeless clouds rolled one upon another below them, and seemed to prevent any return to the earth, which still continued invisible, while the agitation of the balloon became greater every moment. In this extremity they cut the cords which held the interior balloon, and of consequence it fell down upon the aperture of the tube that came from the large balloon into the boat, and stopped it up. They were then driven upwards by a gust of wind from below, which carried them to the top of that stormy vapour in which they had been involved. They now saw the sun without a cloud; but the heat of his rays, with the diminished density of the atmosphere, had such an effect on the inflammable air, that the balloon seemed every moment ready to burst. To prevent this they introduced a stick through the tube, in order to push away the inner balloon from its aperture; but the expansion of the inflammable air pushed it so close, that all attempts of this kind proved ineffectual. It was now, however, become absolutely necessary to give vent to a very considerable quantity of the inflammable air; for which purpose the duke de Chartres himself bored two holes in the balloon, which tore open for the length of seven or eight feet. On this they descended with great rapidity; and would have fallen into a lake, had they not hastily thrown out sixty pounds of ballast, which enabled them just to reach the water's edge.

The success of the scheme for raising or lowering aerostatic machines by means of bags filled with common air being thus rendered dubious, another method was thought of. This was to put a small aerostatic machine with rarefied air under an inflammable air-balloon, but at such a distance that the inflammable air of the latter might be perfectly out of the reach of the fire used for inflating the former; and thus, by increasing or diminishing the fire in the small machine, the absolute weight of the whole would be considerably diminished or augmented. This scheme was unhappily put in execution by the celebrated M. Pilatre de Rozier, and another gentleman named M. Romaine. Their inflammable-air-balloon was about thirty-seven feet in diameter, and the power of the rarefied-air one was equivalent to about sixty pounds. They ascended without any appearance of danger or sinister accident; but had not been long in the atmosphere when the inflammable air-balloon was seen to swell very considerably, at the same time that the aeronauts were observed, by means of telescopes, very anxious to get down, and busied in pulling the valve and opening the appendages to the balloon in order to facilitate the escape of as much inflammable air as possible. A short time after this the whole machine was on fire, when they had then attained the height of about three quarters of a mile from the ground. No explosion was heard; and the silk which composed the air-balloon continued expanded, and seemed to resist the atmosphere, for about a minute; after which it collapsed, and the remains of the apparatus de-

-scended along with the two unfortunate travellers so rapidly, that both of them were killed. M. Pilatre seemed to have been dead before he came to the ground; but M. Romaine was alive when some persons came up to the place where he lay, though he expired immediately after.

Of all the voyages which had been hitherto projected or put in execution, the most daring was that of M. Blanchard and Dr. Jeffries across the straights of Dover, which separate England from France. This took place on the 7th of January 1785, being a clear frosty morning, with a wind barely perceptible, at N. N. W. The operation of filling the balloon began at ten o'clock, and, at three quarters after twelve, every thing was ready for their departure. At one o'clock M. Blanchard desired the boat to be pushed off, which now stood only two feet distant from that precipice so finely described by Shakspeare in his tragedy of King Lear. As the balloon was scarcely sufficient to carry two, they were obliged to throw out all their ballast except three bags of ten pounds each; when they at last rose gently, though making very little way on account of there being so little wind. At a quarter after one o'clock, the barometer, which on the cliff stood at 29.7 inches, was now fallen to 27.3, and the weather proved fine and warm. They had now a most beautiful prospect of the south coast of England, and were able to count thirty-seven villages upon it. After passing over several vessels, they found that the balloon, at fifty minutes after one, was descending, on which they threw out a sack and a half of ballast; but, as they saw that it still descended, and that with much greater velocity than before, they now threw out all the ballast. This still proving ineffectual, they next threw out a parcel of books they carried along with them, which made the balloon ascend when they were about midway betwixt France and England. At a quarter past two, finding themselves again descending, they threw away the remainder of their books, and, ten minutes after, they had a most enchanting prospect of the French coast. Still, however, the machine descended; and, as they had now no more ballast, they were fain to throw away their provisions for eating, the wings of their boat, and every other moveable they could easily spare. "We threw away (says Dr. Jeffries) our only bottle, which, in its descent, cast out a steam like smoke, with a rushing noise; and, when it struck the water, we heard and felt the shock very perceptibly on our car and balloon." All this proving insufficient to stop the descent of the balloon, they next threw out their anchors and cords, and, at last, stripped off their clothes, fastening themselves to certain slings, and intending to cut away their boat, as their last resource. They had now the satisfaction, however, to find that they were rising, and as they passed over the high lands, between Cape Blank and Calais, the machine rose very fast, and carried them to a greater height than they had been at any former part of their voyage. They descended safely among some trees in the forest of Guiennes, where there was just sufficient opening to admit them.

On the 8th of September, 1785, at forty minutes past one, *p. m.* Mr. Baldwin ascended from Chester in M. Lunardi's balloon. After traversing in a variety of different directions, he first alighted, at twenty-eight minutes after three, about twelve miles from Chester, in the neighbourhood of Frodsham; then re-ascending, and pursuing his excursion, he finally landed at Rixton Moss, five miles N. N. E. of

Wavington, and twenty-five miles from Chester. Mr. Baldwin has published his Observations and Remarks made during his voyage, and the following are some of the most important and curious: "The sensation of ascending is compared to that of a strong pressure from the bottom of the car upwards against the soles of his feet. At the distance of what appeared to him seven miles from the earth, though by the barometer scarcely a mile and a half, he had a grand and most enchanting view of the city of Chester, and its adjacent places below. The river Dee appeared of a red colour; the city very diminutive; and the town entirely blue. The whole appeared a perfect plain, the highest building having no apparent height, but reduced all to the same level, and the whole terrestrial prospect appeared like a coloured map. Just after his first ascent, being in a well-watered and maritime part of the country, he observed a remarkable and regular tendency of the balloon towards the sea; but shortly after, rising into another current of air, he escaped the danger: this upper current, he says, was visible to him at the time of his ascent, by a lofty sound stratum of clouds flying in a safe direction. The perspective appearance of things to him was very remarkable. The lowest bed of vapour that first appeared as cloud was pure white, in detached fleeces, increasing as they rose; they presently coalesced, and formed, as he expresses it, a sea of cotton, tufting here and there by the action of the air in the undisturbed part of the clouds. The whole became an extended white floor of cloud, the upper surface being smooth and even. Above this white floor he observed, at great and unequal distances, a vast assemblage of thunder-clouds, each parcel consisting of whole acres in the densest form: he compares their form and appearance to the smoke of pieces of ordnance, which had consolidated as it were into masses of snow, and penetrated through the upper surface or white floor of common clouds, there remaining visible and at rest. Some clouds had motions in slow and various directions, forming an appearance truly stupendous and majestic. He endeavours to convey some idea of the scene by a figure which represents a circular view he had from the car of the balloon, himself being over the centre of the view, looking down on the white floor of clouds, and seeing the city of Chester through an opening, which discovered the landscape below, limited by surrounding vapour to less than two miles in diameter. Mr. Baldwin also gives a curious description of his tracing the shadow of the balloon over tops of volumes of clouds. At first it was small, in shape and size like an egg; but soon increased to the magnitude of the sun's disc, still growing larger, and attended with a most captivating appearance of an iris encircling the whole shadow at some distance round it, the colours of which were remarkably brilliant. The regions did not feel colder, but rather warmer than below. The sun was hottest to him when the balloon was stationary. The discharge of a cannon, when the balloon was at a considerable height, was distinctly heard by the aeronaut; and a discharge from the same piece, when at the height of thirty yards, so disturbed him as to oblige him for safety to lay hold firmly of the cords of the balloon. At a considerable height he poured down a pint bottle full of water; and, as the air did not oppose a resistance sufficient to break the stream into small drops, it mostly fell down in large drops. In the course of the balloon's track it was found much affected by the water (a circumstance observed in former aerial voyages.) At one time

the direction of the balloon kept continually over the water, going directly towards the sea, so much as to endanger the aeronaut; the mouth of the balloon was opened, and he in two minutes descended into an under-current blowing from the sea: he kept descending, and landed at Bellair farm in Rinsley, twelve miles from Chester. Here he lightened his car by thirty-one pounds, and, instantly re-ascending, was carried into the anterior part of the country, performing a number of different manœuvres. At his greatest altitude he found his respiration free and easy. Several bladders which he had along with him crackled and expanded very considerably. Clouds and land, as before, appeared on the same level. By way of experiment, he tried the upper valve two or three times, the neck of the balloon being close; and remarked that the escape of the gas was attended with a growling noise like millstones, but not near so loud. Again, round the shadow of the balloon, on the clouds, he observed the iris. A variety of other circumstances and appearances he met with, which are fancifully described; and at fifty-three minutes after three he finally landed."

The frequency of aerial voyages, accompanied with particular details of trifling and uninteresting circumstances, and apparently made with a view to promote the interest of particular persons, regardless of any advancement in knowledge, have now sunk the science of aerostation so low in the opinion of most people, that, before giving any account of the most proper method of constructing these machines, it may seem necessary to premise something concerning the uses to which they may possibly be applied. These, according to Mr. Cavallo, are the following:

"The small balloons, especially those made of paper, and raised by means of spirit of wine, may serve to explore the direction of the winds in the upper regions of the atmosphere, particularly when it is calm below: they may serve for signals in various circumstances, in which no other means can be used; and letters or other small things may be easily sent by them, as for instance from ships that cannot safely land on account of storms, from besieged places, islands, or the like. The larger aerostatic machines may answer all the above-mentioned purposes in a better manner; and they may, besides, be used as a help to a person who wants to ascend a mountain, a precipice, or to cross a river; and perhaps one of those machines, tied to a boat by a long rope, may be, in some cases, a better sort of sail than any that is used at present. The largest sort of machines, which can take up one or more men, may evidently be subservient to various economical and philosophical purposes. Their conveying people from place to place with great swiftness, and without trouble, may be of essential use, even if the art of guiding them in a direction different from that of the wind should never be discovered. By means of those machines the shape of certain seas and lands may be better ascertained; men may ascend to the tops of mountains they never visited before; they may be carried over marshy and dangerous grounds; they may by that means come out of a besieged place, or an island; and they may, in hot climates, ascend to a cold region of the atmosphere, either to refresh themselves, or to observe the ice, which is never seen below; and, in short, they may be thus taken to several places, to which human art hitherto knew of no conveyance.

"The philosophical uses to which these machines may be subser-

vient are numerous indeed; and it may be sufficient to say, that hardly any thing which passes in the atmosphere is known with precision, and that principally for want of a method of ascending into it. The formation of rain, of thunder-storms, of vapours, hail, snow, and meteors in general, require to be attentively examined and ascertained. The action of the barometer, the refraction and temperature of the air in various regions, the descent of bodies, the propagation of sound, &c. are subjects which all require a series of observations and experiments, the performance of which could never have been properly expected before the discovery of aerostatic machines."

To those uses we may add the gratifications of curiosity and pleasure as a very strong inducement to the practice of an art, in which, with any tolerable degree of caution, there appears not to be the smallest danger. Every one who has tried the experiment testifies, that the beauty of the prospect afforded by an ascent, or the pleasure of being conveyed through the atmosphere, cannot be exceeded. No one has felt the least of that giddiness consequent upon looking from the top of a very high building or of a precipice, nor have they any of the sickness arising from the motion of a vessel at sea. Many have been carried by balloons at the rate of thirty, forty, or even fifty miles an hour, without feeling the least inconvenience, or even agitation of the wind; the reason of which is, that, as the machine moves with nearly the velocity of the wind itself, they are always in a calm, and without uneasiness. Some have apprehended danger from the electricity of the atmosphere; and have thought that a stroke of lightning, or the smallest electric spark, happening near a balloon, might set fire to the inflammable air, and destroy both the machine and the adventurers. Mr. Cavallo has suggested several considerations for diminishing apprehensions of this kind. Balloons have been raised in every season of the year, and even when thunder has been heard, without injury. In case of danger, the aeronauts may either descend to the earth, or ascend above the region of the clouds and thunder-storms. Besides, as balloons are formed of materials that are not conductors of electricity, they are not likely to receive strokes, especially as by being encompassed with air they stand insulated. Moreover, inflammable air by itself, or unmixed with a certain quantity of common air, will not burn; so that, if an electric spark should happen to pass through the balloon, it would not set fire to the inflammable air unless a hole were made in the covering.

The general principles of aerostation are so little different from those of hydrostatics, that it may seem superfluous to insist much upon them. It is a fact universally known, that when a body is immersed in any fluid, if its weight be less than an equal bulk of that fluid, it will rise to the surface; but, if heavier, it will sink; and if equal, it will remain in the place where it is left. For this reason smoke ascends into the atmosphere, and heated air in that which is colder. The ascent of the latter is shewn in a very easy and satisfactory manner by bringing a red-hot iron under one of the scales of a balance, by which the latter is instantly made to ascend; for, as soon as the red-hot iron is brought under the scale, the hot-air, being lighter than that which is colder, ascends, and strikes the bottom, which is thus impelled upwards, and the opposite scale descends, as if a weight had been put into it.

Upon this simple principle depends the whole theory of aerostation;

for it is the same thing whether we render the air lighter by introducing a quantity of heat into it, or inclosing a quantity of gas specifically lighter than the common atmosphere in a certain space; both will ascend, and for the same reason. A cubic foot of air, by the most accurate experiments, has been found to weigh about 554 grains, and to be expanded by every degree of heat, marked on Fahrenheit's thermometer, about $\frac{1}{500}$ part of the whole. By heating a quantity of air, therefore, to 500 degrees of Fahrenheit, we shall just double its bulk when the thermometer stands at fifty-four in the open air, and in the same proportion we shall diminish its weight; and if such a quantity of this hot air be inclosed in a bag, that the excess of the weight of an equal bulk of common air weighs more than the bag with the air contained in it, both the bag and air will rise into the atmosphere, and continue to do so until they arrive at a place where the external air is naturally so much rarefied that the weight becomes equal; and here the whole will float.

The power of hot air in raising weights, or rather that by which it is itself impelled upwards, may be shewn in the following manner: Roll up a sheet of paper into a conical form, and, by thrusting a pin into it, prevent it from unrolling. Fasten it by its apex under one of the scales of a balance by means of a thread, and, having properly counterpoised it by weights put into the opposite scale, apply the flame of a candle underneath; you will instantly perceive the cone to arise, and it will not be brought into equilibrium with the other but by a much greater weight than those who have never seen the experiment would believe. If we try this experiment with more accuracy, by geting proper receptacles made which contain determinate quantities of air, we shall find that the power of the heat depends much more on the capacity of the bag which contains it than could well be supposed. Thus, let a cubical receptacle be made of a small wooden frame covered with paper capable of containing one foot of air, and let the power of a candle be tried with this as above directed for the paper cone. It will be then found that a certain weight may be raised; but a much greater one will be raised by having a receptacle of the same kind which contains two cubic feet; a still greater by one of three feet; a yet greater by one of four feet, &c. and this even though the very same candle be made use of; nor is it known to what extent even the power of this small flame might be carried.

From these experiments it appears, that, in the aerostatic machines constructed on Montgolfier's plan, it must be an advantage to have them as large as possible, because a smaller quantity of fire will then have a greater effect in raising them, and the danger from that element, which in this kind of machines is chiefly to be dreaded, will be in a great measure avoided. On this subject it may be remarked, that as the cubical contents of a globe, or any other figure of which balloons are made, increase much more rapidly than their surfaces, there must ultimately be a degree of magnitude at which the smallest imaginable heat would raise any weight whatever. Thus, supposing any aerostatic machine capable of containing 500 cubic feet, and the air within it to be only one degree hotter than the external atmosphere; the tendency of this machine to rise, even without the application of artificial heat, would be near an ounce. Let its capacity be increased sixteen times; and the tendency to rise will be equivalent to a pound, though this may be

done without making the machine sixteen times heavier than before. It is certain, however, that all aerostatic machines have a tendency to produce or preserve heat within them, which would by no means be imagined by those who have not made the experiment. When Messrs. Charles and Robert made their longest aerial voyage of 150 miles, they had the curiosity to try the temperature of the air within their balloon, in comparison with that of the external atmosphere; and at this time they found, that, when the external atmosphere was 63°, the thermometer within the balloon stood at 104°. Such a difference of temperature must have given a machine of the magnitude which carried them a considerable ascending power independent of any other cause, as it amounted to forty-one grains on every cubic foot; and therefore in a machine containing 50,000 such feet would have been almost 200 pounds.

This difference between the external and internal heat, being so very considerable, must have a great influence upon aerostatic machines, and will undoubtedly influence these filled with inflammable air as well as the other kind. Nor is it unlikely, that the short time which many aerial voyagers have been able to continue in the atmosphere may have been owing to the want of a method of preserving this internal heat. It may naturally be supposed, and indeed it has always been found, that balloons, in passing through the higher regions of the atmosphere, acquire a very considerable quantity of moisture, not only from the rain or snow they sometimes meet with, but even from the dew and vapour which condense upon them. On this an evaporation will instantly take place; and, as it is the property of this operation to produce a very violent cold, the internal heat of the balloon must be soon exhausted in such a manner as to make it become specifically heavier than the common atmosphere, and consequently descend in a much shorter time than it would have done by the mere loss of air. To this in all probability we are to ascribe the descent of the balloon which carried Messrs. Blanchard and Jeffries; and which seemed so extraordinary to many people, that they were obliged to have recourse to an imaginary attraction in the waters of the ocean, in order to solve the phenomenon. This supposition is rejected by Mr. Cavallo; who explains the matter by remarking, that, in two former voyages made with the same machine, it could not long support two men in the atmosphere; so that we had no occasion to wonder at its weakness on this occasion. "As for its rising higher (says he) just when it got over the land, that may be easily accounted for. In the first place, the travellers threw out their clothes just about that time; secondly, in consequence of the wind's then increasing, the balloon travelled at a much greater rate than it had done whilst over the sea; which increase of velocity lessened its tendency to descend; besides which, the vicissitudes of heat and cold may produce a very considerable effect; for, if we suppose that the air over the land was colder than that over the sea, the balloon, coming into the latter from the former, continued to be hotter than the circumambient air for some time after; and consequently, it was comparatively much lighter when in the colder air over the land, than when in the hotter air over the sea; hence it floated easier in the former than it did in the latter case."

It seems indeed very probable, that there was something uncommon in the case of M. Blanchard's balloon while passing over the sea; for,

as it rose higher after reaching the land than in any former period of the voyage, and likewise carried them to the distance over land more than half of that which they had passed over water, we can scarcely avoid supposing, that it had a tendency to descend when over the water more than when over land, independent of any loss of air. Now, it does not appear that the air over the sea is at all warmer than that above land; on the contrary, there is every reason to believe, that the superior reflective power of the land renders the atmosphere above it warmer than the sea can do: but it is very natural to suppose, that the air above the sea is more moist than that above land; and consequently, by letting fall its moisture upon the balloon, must have occasioned an evaporation that would deprive the machine of its internal heat, which it would partly recover after it entered the warmer and drier atmosphere over land.

We shall now proceed to the construction of aerostatic machines. Various shapes have been tried and proposed, but the globular, or the egg-like figure, is the most proper and convenient, for all purposes; and this form also will require less cloth or silk than any other shape of the same capacity; so that it will both come cheaper, and have a greater power of ascension. The bag or cover of an inflammable air balloon, is best made of the silk stuff called lustring, varnished over. But for a Montgolfier, or heated air balloon, on account of its great size, linen-cloth has been used, lined within or without with paper, and varnished. Small balloons are made either of varnished paper, or simply of paper unvarnished, or of gold-beater's skin, or such like light substances.

With respect to the form of a balloon, it will be necessary that the operator remember the common proportions between the diameters, circumferences, surfaces, and solidities of spheres; for instance, that of different spheres, the circumferences are as the diameters; that the surfaces are as the squares of the diameters; and the solidities as the cubes of the same diameters: that any diameter is to its circumference as 7 to 22, or as 1 to $3\frac{1}{7}$; and therefore 3 times and $\frac{1}{7}$ of any diameter will be its circumference; so that, if the diameter of a balloon be 35 feet, its circumference will be 110 feet. And, if the diameter be multiplied by the circumference, the product will be the surface of the sphere; thus 35 multiplied by 110 gives 3850, which is the surface of the same sphere in square feet: and if this surface be divided by the breadth of the stuff, in feet, which the balloon is to be made of, the quotient will be the number of feet in length necessary to construct the balloon; so, if the stuff be three feet wide, then 3850 divided by 3 gives $1283\frac{1}{3}$ feet, or 428 yards nearly, the requisite quantity of stuff of one yard wide, to form the balloon of 35 feet diameter. Hence also, by knowing the weight of a given piece of the stuff, as of a square foot, or square yard, it is easy to find the weight of the whole bag, namely, by multiplying the surface in square feet or yards, by the weight of a square foot or yard: so if each square yard weigh 16 oz. or 1lb. then the whole bag will weigh 428lbs. Again, the capacity, or solid contents of the sphere, will be found by multiplying $\frac{1}{6}$ of the surface by the diameter, or by taking $\frac{11}{21}$ of the cube of the diameter: which gives 22,458 cubic feet for the capacity of the said balloon, that is, it will contain, or displace, 22,458 cubic feet of air. From the contents and surface of the balloon, so found, is to be derived its power or levi-

ty, thus: on an average, a cubic foot of common air weighs $1\frac{1}{5}$ ounce; and therefore to the number 22,458, which is the content of the balloon, adding its $\frac{1}{5}$th part, we have 26,950 oz. or 1684lbs. for the weight of the common air displaced or occupied by the balloon. From this weight must be deducted the weight of the bag, namely 428lbs. and then there remains 1256lbs. levity of the balloon, without, however, considering the contained air, whether it be heated air, or of the inflammable kind. If inflammable air be used, as it is of different weights, from $\frac{1}{4}$ to $\frac{1}{10}$ or $\frac{1}{12}$ the weight of common air, according to the modes of preparing it; let us suppose for instance that it is $\frac{1}{6}$ of the weight of common air; then $\frac{1}{5}$ of 1684 is 261lbs. which is the weight of the bag full of that air; which, being taken from 1256, leaves 995lbs. for the levity of the balloon when so filled with that inflammable air, or the weight which it will carry up, consisting of the car, the ropes, the passengers, the necessaries, and ballast. But, if heated air be used, then as it is known from experiment that, by heating, the contained air is diminshed in density about one-third only, therefore from 1684 take $\frac{1}{3}$ of itself, and their remains 1123 for the weight of the contained warm air; and this being subtracted from 1256, leaves only 133lbs. for the levity of the balloon in this case; which being too small to carry up the car, passengers, &c. it shews that for those purposes a larger balloon is necessary, on Montgolfier's principle. But if now, from the preceding computation, it be required to find how much the size of the balloon must be increased, that its levity, or power of ascension, may be equal to any given weight, as suppose 1000lbs. then, because the levities are nearly as the cubes of the diameters, therefore the diameters will be nearly as the cube roots of the levities; but the levities 133 and 1000 are nearly as 1 to 8, the cube roots of which are as 1 to 2, and consequently 1 : 2 : : 35 : 70 feet, the diameter of a Montgolfier, made of the same thickness of stuff as the former, capable of lifting 1000lbs.

On the same principle we can easily find the size of a balloon that shall just float in air when made of stuff of a given thickness or weight, and filled with air of a given density; the rule for which is this: from the weight of a cubic foot of common air, subtract that of a cubic foot of the lighter or contained air; then divide 6 times the weight of a square foot of the stuff, by the remainder, and the quotient will be the diameter, in feet, of the balloon that will just float at the surface of the earth. Suppose, for instance, that the materials are as before, namely, the stuff 1lb. to the square yard, or $\frac{16}{9}$ ounces to the square foot, which taken 6 times is $\frac{32}{3}$; then the cubic foot of common air weighing $1\frac{1}{5}$ ounce, and of heated air $\frac{2}{3}$ of the same, whose difference is $\frac{2}{5}$; therefore $\frac{32}{3}$ divided by $\frac{2}{5}$, gives $26\frac{2}{3}$ feet, which is the diameter of a Montgolfier that will just float: but, if inflammable air be used of $\frac{1}{6}$ the weight of common air, the difference between $1\frac{1}{5}$ and $\frac{1}{6}$ of it is 1; by which dividing $\frac{32}{3}$ or $10\frac{2}{3}$, the quotient is the same, $10\frac{2}{3}$ feet, which therefore is the diameter of an inflammable air balloon that will just float. And, if the diameter be more than these dimensions, the balloons will rise up into the atmosphere.

The height nearly to which a given balloon will rise in the atmosphere, may be thus found, having given only the diameter of the balloon, and the weight which just balances it, or that is just necessary to keep it from rising: compute the capacity or content of the globe in cubic feet, and divide its restraining weight in ounces by that content, and the quotient will be the difference between the density or specific gravity of the atmosphere at the earth's surface, and that at the height to which the balloon will rise; therefore subtract that difference of quotient from $1\frac{1}{5}$ or 1.2, the density at the earth, and the remainder will be the density at that height: then the height answering to that density will be found sufficiently near in the annexed table. Thus, in the foregoing examples in which the diameter of the balloon is 35 feet, its capacity 22,458, and the levity of the first one 995 pounds, or 15,920 ounces, the quotient of the latter number, divided by the former, is .709, which is the density at the utmost height, and to which in the table answers a little more than $2\frac{1}{2}$ miles, or $2\frac{5}{8}$ miles nearly, which therefore is the height to which the balloon will ascend. And, when the same balloon was filled with heated air, its levity was found equal to only 133 pounds, or 2128 ounces; then dividing this by 22,458, the capacity, the quotient .095, taken from 1.200, leaves 1.105 for the density; to which in the table corresponds almost half a mile, or nearer $\frac{3}{8}$ of a mile. And so high nearly would these balloons ascend, if they keep the same figure, and lose none of the contained air: or rather, those are the heights they would settle at; for their acquired velocity would first carry them above that height, so far as till all their motion should be destroyed; then they would descend and pass below that height, but not so much as they had gone above; after which they would re-ascend, and pass that height again, but not so far as they had gone below it; and so on for many times, vibrating alternately above and below that point, but always less and less every time. The foregoing rule, for finding the height to which the balloon will ascend, is independent of the different states of the thermometer at that highest point, and at the surface of the earth.

Height in miles.	Density.
0	1.200
$\frac{1}{4}$	1.141
$\frac{1}{2}$	1.085
$\frac{3}{4}$	1.031
1	0.980
$1\frac{1}{4}$	0.932
$1\frac{1}{2}$	0.886
$1\frac{3}{4}$	0.842
2	0.800
$2\frac{1}{4}$	0.761
$2\frac{1}{2}$	0.723
$2\frac{3}{4}$	0.687
3	0.653

The best way to form the whole coating of the balloon is by different pieces or slips joined lengthways from end to end, like the pieces composing the surface of a geographical globe, and contained between one meridian and another, or like the slices into which a melon is usually cut, and supposed to be spread flat out. Now the edges of such pieces cannot be exactly described by a pair of compasses, not being circular, but flatter or less round than circular arches; but, if the slips are sufficiently narrow, or numerous, they will differ the less from circles, and may be described as such. But more accurately, the breadths of the slip, at the several distances from the point to the middle, where it is broadest, are directly as the sines of those distances, radius being the sine of the half length of the slip, or of the distance of either point from the middle of the slip.

The joining the pieces of stuff may be rendered secure by running them with a silk thread, and sticking a ribband over the seam with

common glue; and, when dry, varnish them over, to prevent their being unglued by wet.

The best varnish for an inflammable air balloon is that made with bird-lime, and recommended by M. Faujas de Saint Fond, in a treatise published on the subject. The following is his method of preparing it: "Take one pound of bird-lime, put it into a new earthen pot that can resist the fire, and let it boil gently for about one hour, viz. till it ceases to crackle, then pour upon it a pound of spirit of turpentine, stirring it at the same time with a wooden spatula, and keeping the pot at a good distance from the flame, lest the vapour of this essential oil should take fire. After this, let it boil for about six minutes longer; then pour upon the whole three pounds of boiling oil of nut, linseed, or poppy, rendered drying by means of litharge; stir it well, let it boil for a quarter of an hour longer, and the varnish is made. After it has rested for twenty-four hours, and the sediment has gone to the bottom, decant it into another pot; and, when you want to use it, warm, and apply it with a flat brush upon the silk or stuff, whilst that is kept well stretched. One coat of it may be sufficient; but, if two are necessary, it will be proper to give one on each side of the silk, and to let them dry in the open air while the silk remains extended."

M. Cavallo gives the following method of preparing this varnish, which he prefers to that of M. de Saint Fond:—"In order to render linseed-oil drying, boil it with two ounces of saccharum saturni and three ounces of litharge, for every pint of oil, till the oil has dissolved them, which will be accomplished in half an hour; then put a pound of bird-lime, and half a pint of the drying oil into a pot (iron or copper pots are the safest for this purpose), the capacity of which may be equal to about one gallon, and let it boil very gently over a slow charcoal fire till the bird-lime ceases to crackle; then pour upon it two pints and a half more of drying oil, and let it boil for one hour longer, stirring it very frequently with an iron or wooden spatula. Whilst the stuff is boiling, the operator should, from time to time, examine whether the varnish has boiled enough; which is thus known:—Take some of it upon the blade of a knife, and then, after rubbing the blade of another knife upon it, separate the knives; and when, on this separation, the varnish begins to form threads between the two, you may conclude that it is done; and, without losing time, it must be removed from the fire. When it is almost, though not quite cold, add about an equal quantity of spirit of turpentine: mix it well together, and let it rest till the next day; when, having warmed it a little, strain and bottle it for use."

The best method of cutting the pieces of silk that are to form a balloon, is to describe a pattern of wood or stiff card-paper, and then to cut the silk upon it. In cutting the pieces after such pattern, care should be taken to leave them about three-quarters of an inch all round larger than the pattern, which will be taken up by the seams in joining.

To the upper part of the balloon there should be adapted, and well fitted in, a valve opening inwards; to which should be fastened a string passing through a hole made in a small piece of round wood fixed in the lowest part of the balloon opposite to the valve, the end of this string fastened in the car below, so that the aeronaut may open the valve when occasion requires. The action of this valve is effected by a round brass plate, having a round hole about two or three inches dia-

meter, covered on both sides with strong smooth leather. On the inside there is a shutter of brass, covered with leather, which serves to close the hole, being about two inches larger in diameter than the hole. It is fastened to the leather of the plate, and by a spring, which need not be very strong, it is kept against the hole. The elasticity of the gas itself will help to keep it shut. To this shutter the string is fastened, by which it is occasionally opened for the escape of the gas. A small string or other security should be fixed to the shutter and the plate, so as not to admit the shutter to be opened beyond a certain safe distance. To the lower part of the balloon two pipes should be fixed, made of the same stuff as the envelope; they should be six inches diameter for a balloon of thirty feet, and proportionably larger for balloons of a greater capacity. They must be long enough to reach the car. For balloons of eighteen feet and less diameter, one neck or pipe will be sufficient. These pipes are the apertures through which the inflammable gas is introduced into the balloon.

The car or boat is best made of wicker-work, covered with leather, and well painted or varnished over; and the proper method of suspending it, is by ropes proceeding from the net which goes over the balloon. This net should be formed to the shape of the balloon, and fall down to the middle of it, with various cords proceeding from it to the circumference of a circle about two feet below the balloon; and from that circle other ropes should go to the edge of the boat. This circle may be made of wood, or of several pieces of slender cane bound together. The meshes of the net may be small at top, against which part of the balloon the inflammable air exerts the greatest force; and increase in size as they recede from the top. A hoop has been sometimes applied round the middle of the balloon to fasten the net. This, though not absolutely necessary, is best made of pieces of cane bound together, and covered with leather.

With regard to the rarefied air machines, Mr. Cavallo recommends first to soak the cloth in a solution of sal-ammoniac and common size, using one pound of each to every gallon of water; and, when the cloth is quite dry, to paint it over in the inside with some earthy colour, and strong size or glue. When this paint has dried perfectly, it will then be proper to varnish it with oily varnish, which might dry before it could penetrate quite through the cloth. Simple drying linseed oil will answer the purpose as well as any, provided it be not very fluid.

It now only remains to give some account of the method by which aerostatic machines may be filled with their proper gas, in order to give them their power of ascending into the atmosphere; and here we are enabled to determine with much greater precision concerning the inflammable air balloons than the others. With regard to them, a primary consideration is, the most proper method of procuring the inflammable air. It may be obtained in various ways, as has been shewn under the article aerology. But the most advantageous methods are, by applying acids to certain metals; by exposing animal, vegetable, and some mineral substances, in a close vessel, to a strong fire; or by transmitting the vapour of certain fluids through red hot tubes.

In the first of these methods, iron, zinc, and vitriolic acid, are the materials most generally used. The vitriolic acid must be diluted by five or six parts of water. Iron may be expected to yield in the com-

mony way 1700 times its own bulk of gas.; or one cubic foot of inflammable air to be produced by four ounces and a half of iron, the like weight of oil of vitriol, and twenty-two ounces and a half of water. Six ounces of zinc, an equal weight of oil of vitriol, and thirty ounces of water, are necessary for producing the same quantity of gas. It is more proper to use the turnings or chippings of great pieces of iron, as of cannon, &c. than the filings of that metal, because the heat attending the effervescence will be diminished; and the diluted acid will pass more readily through the interstices of the turnings when they are heaped together, than through the filings, which stick closer to one another. The weight of the inflammable air thus obtained by means of acid of vitriol, is, in the common way of procuring it, generally one-seventh part of the weight of common air; but, with the necessary precautions for philosophic experiments, less than one-tenth of the weight of common air. Two other sorts of elastic fluids are sometimes generated with the inflammable air. These may be separated from it by passing the inflammable air through water in which quick-lime has been dissolved. The water will absorb these fluids, cool the inflammable air, and prevent its over-heating the balloon when introduced into it.

Inflammable air may be obtained at a much cheaper rate by the action of fire on various substances; but the gas which these yield is not so light as that produced by the effervescence of acids and metals. The substances proper to be used in this way are, pit-coal, asphaltum, amber, rock-oil, and other minerals; wood and especially oak, camphor-oil, spirit of wine, ether, and animal substances, which yield air in different degrees, and of various specific gravities; but pit-coal is the preferable substance. A pound of this exposed to a red heat yields about three cubic feet of inflammable air, which, whether it be passed through water or not, weighs about one-fourth of the weight of common air. Dr. Priestley found that animal or vegetable substances will yield six or seven times more inflammable air when the fire is suddenly increased than when it is gently raised, though it be afterwards made very strong. Mr. Cavallo observes, that the various substances above enumerated generally yield all their inflammable air in about an hour's time. The general method is, to enclose the substances in iron or earthen vessels, and thus expose them to a strong fire sufficient to make the vessels red-hot: the inflammable air proceeding from the aperture of the vessel is received into a tube or refrigeratory, and, passing through the tube or worm, is at last collected in a balloon or other vessel. A gun-barrel has often been used for essays of this kind. The substance is put into it so as to fill six or eight inches of its lowest part, the remainder filled with dry sand: a tube, adapted to the mouth of the barrel, is brought into a bason of water under an inverted receiver; and, the part of the barrel containing the substance being put into the fire and made red-hot, the inflammable air is collected in the inverted receiver. As the gun-barrel cannot serve for producing a large quantity of inflammable air, Mr. Cavallo recommends, as the most advantageous shape, the following contrivance:—Let the vessel be made of clay, or rather of iron, in the shape of a Florence flask, somewhat larger, and whose neck is longer and larger. Put the substance to be used into this vessel, so as to fill about four-fifths or less of its cavity. If the substance is of such a nature as to swell much by the action of the fire, lute a tube of brass, or first a brass and then a leaden tube, to the neck of the vessel; and let

the end of the tube be rounded, so that, going into the water of a tub, it may terminate under a sort of inverted vessel, to the upper aperture of which the balloon is adapted. Things thus prepared, if the lower part of the vessel be put into the fire, and made red-hot, the inflammable air produced will come out of the tube, and, passing through the water, will at last enter into the balloon. Previous to the operation, as a considerable quantity of common air remains in the inverted vessel, which it is more proper to expel, the vessel should have a stop-cock, through which the common air may be sucked out, and the water ascend as high as the stop-cock. Care must be taken that the fire used in this process be at a sufficient distance, otherwise it may happen to fire the inflammable air.

Another method of obtaining inflammable air was lately discovered by M. Lavoisier, and also by Dr. Priestley. M. Lavoisier made the steam of boiling water pass through the barrel of a gun, kept red-hot by burning coals. Dr. Priestley uses, instead of the gun-barrel, a tube of red-hot brass, upon which the steam of water has no effect, and which he fills with the pieces of iron which are separated in the boring of cannon. By this method he obtains an inflammable air, the specific gravity of which is to that of common air as one to thirteen. In this method, a tube about three-quarters of an inch in diameter, and about three feet long, is filled with iron-turnings; then the neck of a retort, or close boiler, is luted to one of its ends, and the worm of a refrigeratory is adapted to its other extremity. The middle part of the tube is then surrounded with burning coals, so as to keep about one foot in length of it red-hot, and a fire is always made under the retort or boiler sufficient to make the water boil with vehemence. In this process a considerable quantity of inflammable air comes out of the worm of the refrigeratory. It is said that iron yields one half more air by this means than by the action of vitriolic acid.

For filling large balloons, a greater apparatus is necessary; and the only materials that can, with any certainty of success, be employed for producing the proper gas, are, oil of vitriol, and iron filings or turnings.

It has indeed been recommended to use zinc instead of iron-filings, because white vitriol, the salt produced by the union of the vitriolic acid and zinc, is much more valuable than the green sort produced by the union of the same acid with iron. But, though this is undoubtedly the case, it will as certainly be found, upon trial, that the superior price of the zinc will be more than an equivalent for all the advantage that can be derived from the additional price of the white vitriol. For a balloon of thirty feet diameter, Mr. Cavallo recommends 3900 pounds of iron-turnings, as much oil of vitriol, and 19,500 pounds of water. These proportions, however, appear too great with respect to the acid and metal, and too little with respect to the water. Oil of vitriol will not exert its power upon iron unless it be diluted with five or six times its quantity of water; in which case a much smaller quantity of both acid and metal will serve. M. Lunardi, who from the number of his voyages had certainly much practical knowledge in aerostation, filled his balloon with about 2000 pounds of iron, as much vitriolic acid, and 12,000 pounds of water. The iron was placed in his vessels in layers, with straw between them, in order to increase the surface. His apparatus was not materially different from that of Mr. Cavallo, and is represented in the plate, where there are two tubs, about three feet in

diameter and nearly two feet deep, inverted in large tubs filled with water. In the bottom of each of the inverted tubs a hole is made, and a tube of tin adapted, which is about seven inches in diameter, and seven or eight long. To these tubes the silken ones of the balloon are tied. Round each of the tubs, five, six, or more, strong casks are placed; in the top of each two holes are made, and to one of these holes a tin tube is adapted, and so shaped, that, passing through the water, it may terminate with its aperture under the inverted tub. The other hole of these casks serves for the introduction of materials, and is stopped with a wooden plug. When the balloon is to be filled, put the net over it, and let it be suspended in the centre; and, having expelled all the common air from it, let the silken tubes be fastened round the tin ones, and, the materials being put into the casks, the inflammable air, passing into the balloon, will soon distend, and render it capable of supporting itself; after which the rope may be slipped off. As the balloon continues to be filled, the net is adjusted properly round it, and the boat, being placed between the two sets of casks, is fastened to the hoop, with every thing else that is required to be sent up, as ballast, instruments, &c. At last, when the balloon is little more than three quarters full, the silken tubes are separated from the tin ones of the inverted tubs, and, their extremities being tied up, are placed in the boat. Lastly, the aeronauts being seated in the boat, the lateral ropes are slipped off, and the machine is abandoned to the air. This apparatus was at last reduced by M. Lunardi to its utmost simplicity, by using only two large casks, and suffering the vapour to go into the balloon without passing through water. Thus his balloon was filled in less than half an hour, when, by the former method, it had required two hours at least. The sinking of his casks in the ground was also an additional convenience, as it created no confusion, and rendered the materials much more easily conveyed into them.

With regard to the rarefied air balloons, the method of filling them is as follows:—A scaffold, the breadth of which is at least two-thirds of the diamenter of the machine, is elevated about six or eight feet above the ground. From the middle of it descends a well, rising about two or three feet above it, and reaching to the ground, furnished with a door or two, through which the fire in the well is supplied with fuel. The well should be constructed of brick or of plastered wood, and its diameter should be somewhat less than that of the machine. On each side of the scaffold are erected two masts, each of which has a pulley at the top, and rendered firm by means of ropes. The machine to be filled is to be placed on the scaffold, with its neck round the aperture of the well. The rope, passing over the pulleys of the two masts, serves, by pulling its two ends, to lift the balloon about fifteen feet or more above the scaffold. The machine is kept steady, and held down, whilst filling, by ropes passing through loops or holes about its equator; and these ropes may easily be disengaged from the machine, by slipping them through the loops when it is able to sustain itself. The proper combustibles to be lighted in the well, are those which burn quick and clear, rather than such as produce much smoke; because it is hot air, and not smoke, that is required to be introduced into the machine. Small wood and straw have been found to be very fit for this purpose. Mr. Cavallo observes, as the result of many experiments with small machines, that spirits of wine are upon the whole the best combustible; but its price

may prevent its being used for large machines. As the current of hot air ascends, the machine will soon dilate, and lift itself above the scaffold and gallery which was covered by it. The passengers, fuel, instruments, &c. are then placed in the gallery. When the machine makes efforts to ascend, its aperture must be brought, by means of the ropes annexed to it, towards the side of the well a little above the scaffold; the fire-place is then suspended in it, the fire lighted in the grate, and, the lateral ropes being slipped off, the machine is abandoned to the air. It has been determined by accurate experiments, that only one-third of the common air can be expelled from these large machines; and therefore the ascending power of the rarefied air in them can be estimated as only equal to half an ounce avoirdupoise, for every cubic foot.

The conduct of balloons, when constructed, filled, and actually ascending in the atmosphere, is an object of great importance in the practice of aerostation. The method generally used for elevating or lowering the balloons with rarefied air, has been the increase or diminution of the fire; and this is entirely at the command of the aeronaut, as long as he has any fuel in the gallery. The inflammable air balloons have been generally raised or lowered by diminishing the weight in the boat, or by letting out some of the gas through the valve; but the alternate escape of the air in descending, and discharge of the ballast for ascending, will by degrees render the machine incapable of floating; for in the air it is impossible to supply the loss of ballast, and very difficult to supply that of inflammable air. These balloons will also rise or fall by means of the rarefaction or condensation of the inclosed air, occasioned by heat and cold. It has been proposed to aid a balloon in its alternate motion of ascent and descent, by annexing to it a vessel of common air, which might be condensed for lowering the machine, and rarefied again, by expelling part of it, for raising the machine. But a vessel adapted to this purpose must be very strong; and, after all, the assistance afforded by it would not be very considerable. M. Maunier, in order to attain this end, proposes to inclose one balloon filled with common air in another filled with inflammable air; as the balloon ascends, the inflammable air is dilated, and of course compresses the internal balloon containing the common air; and, by diminishing its quantity, lessens its weight. If it should be necessary to supply this loss, he says it may be easily done by a pair of bellows fixed in the gallery. Others have proposed to annex a small machine with rarefied air to an inflammable air-balloon by ropes, at such a distance that the fire of the former might not affect the inflammable air of the latter: the whole apparatus, thus combined, of balloons formed on the two principles of heated and inflammable air, might be raised or lowered by merely increasing or diminishing the fire in the lower balloon.

Wings or oars are the only means of this sort that have been used with some success; and, as Mr. Cavallo observes they seem to be capable of considerable improvement. Although great effects are not to be expected from them, when the machine goes at a great rate, the best methods of moving those wings are by the human strength applied similarly to the oars of a waterman. They may be made in general of silk stretched between wires, tubes, or sticks; and, when used, must be turned edgewise when they are moved in the direction in which the machine is intended to be impelled, but flat in the opposite direction. Other contrivances have been made to direct aerostatic machines, but

they have mostly been invented to effect a power upon them as upon a ship. It appears, however, that they can have no effect when a machine is only moved by the wind alone, because the circumambient air is at rest in respect to the machine. The case is quite different with a vessel at sea, because the water on which it floats stands still while the vessel goes on; but it must be time and experience that can realise the expectations suggested by these contrivances.

Mr. Sadler, of Oxford, was the first Englishman who ascended with a balloon. He constructed one himself, with which he rose from Oxford on the 4th of October; and a second time on the 12th, and sailed 15 miles in 18 minutes.

M. Blanchard and Mr. Sheldon ascended from Chelsea, on the 16th of the same month; and Mr. Sheldon having alighted about 14 miles from that place, M. Blanchard pursued his journey alone, and landed near Rumsey, in Hampshire.

Mr. Harper, on the 4th of January 1785, ascended from Birmingham, and sailed to the distance of 57 miles in an hour and 20 minutes.

Mr. Crosbie ascended from Dublin, on the 19th of the same month, with such rapidity, that he was out of sight in three minutes, and descended at the verge of the sea.

Count Zambecari and Admiral Sir Edward Vernon, on 23d of March, sailed from London to Horsham, a distance of 33 miles, in less than an hour.

Mr. Sadler and Mr. W. Windham, on the 5th of May, ascended from Moulsey-Hurst, and descended at the conflux of the Thames and Medway.

Mr. M'Guire, on the 12th of May, having ascended from Dublin, was carried with great velocity towards the sea, into which he descended, and was taken up by a boat, when on the point of expiring with fatigue.

M. Pilatre de Rozier and M. Romain, on the 15th of July, ascended from Boulogne, with an intention of crossing the Channel, but their balloon, being a Montgolfier, or fire balloon, took fire at the height of 1200 yards, and they fell to the ground and were dashed to pieces.

Mr. Crosbie, on the 19th of July, again ascended from Dublin, intending to cross the Channel, and land in England; but he fell into the sea, and was with great difficulty saved from being drowned.

Major Money, on the 22d of the same month, also ascended at Norwich, and experienced a similar mischance. He was driven out to sea, and fortunately snatched from death by a revenue-cutter.

M. Blanchard, in August, made an aerial voyage from Lisle, to the distance of 300 miles, before he descended. He had also a parachute attached to his car; with this he dropped a dog, which descended gently and without injury.

Mr. Lunardi, on the 5th of October 1785, made the first aerial voyage in Scotland. He ascended from Edinburgh, and landed at Cupar, in Fife, having traversed a distance of fifty miles over sea and land in an hour and a half.

M. Blanchard, on the 19th of November, ascended from Ghent, to a great height, and landed at Delft, having cut away his car, to lighten the balloon, which was descending too rapidly, and held fast by the cords, which then served as a parachute.

Mr. Lunardi, on the 25th of November, again ascended at Glasgow,

and travelled a distance of 125 miles. He says, that being overcome with drowsiness during his voyage, he lay down in his car, and slept for about twenty minutes.

M. Blanchard, in August 1788, made his thirty-second voyage from Brunswick.

The rage for aerostatic experiment now almost entirely subsided; and the French were the only people who paid any attention to it during the period of the late war. The principal improvement was, the addition of a large parachute, or umbrella, suspended below the balloon, by means of which, the aerostat may come down very gently and in perfect safety, should any accident happen to the balloon, so that he should be forced to quit it.

The parachute is one of the material adjuncts to the air-balloon, and for this we are indebted to M. Garnerin.

At five o'clock, on the 28th June 1802, that gentleman ascended from Ranelagh-gardens, accompanied by Capt. Sowden. The weather was very boisterous. In three quarters of an hour they landed, and found themselves four miles beyond Colchester, which was at the rate of 70 miles per hour. They experienced considerable danger in alighting, owing to the violence of the wind; but they met with no material injury.

On the 3d July, he again ascended from Lord's Cricket-ground, accompanied by Mr. Locker, and descended at Chingford, in Essex, passing a distance of nine miles in one quarter of an hour. They descended in perfect safety.

On September 21, 1802, M. Garnerin ascended alone from St. George's-parade, North Audley-street, Grosvenor-square, for the purpose of descending in his parachute. He went to the height of 8000 feet before he cut away the parachute, to which he was suspended. His descent for the first thirty seconds was astonishingly rapid. The parachute then expanded, and came down steadily; but it soon began to swing; and this motion increased to such a degree, that all were alarmed for the safety of the aeronaut. When it came near to the earth the swinging motion decreased, and he alighted without any injury. The velocity with which he came to the ground was the same as if he had leaped from a height of four feet.

The safety of the balloon, when properly constructed, is testified by the numerous aerial voyages of Mr. Sadler; the most important of whose excursions is thus described by his companion, Henry Beaufoy, Esq. The ascent was from Hackney, August 2, 1811. As the balloon ascended I was totally unconscious of the motion; it appeared as if the balloon was the only point stationary, and that the earth and the people were suddenly sinking away. The rapidity with which it ascended was such that it prevented every sensation of giddiness, the whole country appearing in the course of a few seconds as one prodigious map. The almost instantaneous transition from the shouts of the spectators, and from the absolute tumult in which we had been engaged, to the death-like stillness that reigned in the upper regions, only broken at intervals by the report of a cannon at Walthamstow, filled the mind with indescribable sensations. It appeared difficult to persuade the mind that it was a reality; and the mixed sensations of delight and astonishment completely deprived me of the power of expressing my wonder at the scene beneath the eye. It seemed a dream, and hardly possible to be a reality.

A few moments, however, were all that I allowed myself to feast on the delightful scene; for the confusion that had taken place around the car had compelled those that had taken charge of the instruments to use very great exertions to convey them to us in the car. They were accordingly lying in a distressing state of confusion at the bottom of the car; though on examination, fortunately without having suffered the smallest injury. As soon therefore as the usual ceremony of waving the farewell flag could be dispensed with, I threw off my hat, and proceeded to arrange and suspend the instruments. To effect this it was necessary to have both hands at liberty. I was desirous of disposing of the flag I held in my hand, and accordingly thrust the staff through the back of the car; but as I was obliged to stand upon the seat to fix the barometer sufficiently high, the flag fell from its situation, and was afterwards picked up at about a quarter of a mile from the place of ascent, though neither of us missed it until some considerable time after the accident. The instruments being fixed in their respective situations, the next care was to regulate the gauge of the barometer; all which several occupations consumed the first ten minutes of the voyage.

After having made the first set of observations, I had an opportunity of viewing at leisure the prospect from the balloon. The first and most striking object was the Thames, which was seen meandering in endless gigantic sinuosities through the long line of country down as far as the Nore. The ships, and even boats, were distinguishable on its mirror-like surface with astonishing minuteness; and I have no doubt that, had the ascent been made with reference to that particular object, the number of shipping afloat in the river and wet docks might have been most accurately counted.

The sun shone full upon the river, and presented at once the grandest and most delightful sight imaginable. It would be fruitless to attempt the description of the scene, though in candour it must be acknowledged that it agreed precisely with the idea that I had preconceived, and differed in no respect whatever from the view from the summit of a lofty situation; except that it was infinitely more extended in its range; the eye embraced a larger field within its scope; and then that listless sensation of delight which is derived from the nature of the voyage itself. In short, as has been already stated, the gratification arising from the situation is altogether indescribable, but to such as have experienced it themselves. Though moving with such wonderful velocity, the travellers are themselves totally unconscious of any motion whatever. They feel themselves floating in a most delightful aeriform fluid, and seeming to convey a most exquisite idea of unlimited elasticity. The extreme elasticity, indeed, was found on this occasion to be materially against the accuracy required in all barometrical observations. The slightest motion on the part of either of us causing a vibration of the quicksilver, in the tube, of an inch, a half, and two inches, which required to be steadied with the hand to bring it to any thing like a stationary point. Finding this to be the case, I noticed each time the two extreme divisions of vibration, and took the mean as the sum to be placed in the barometer column. In no one instance was the barometer stationary; for even when we were both of us perfectly still, the barometer ebbed and flowed with great rapidity, though not to such an extent as in the case already mentioned.

In looking over the country, it gave the idea of an immense map,

executed with uncommon neatness; the fields presenting a much livelier and brighter green than the trees. The colours of objects were not in the least changed or affected in any instance than came under observation. In passing over Epping Forest, I was particularly struck with its appearance; it seemed to consist of a vast number of clumps of something of a very dark green, certainly conveying an accurate idea of what it really was—a forest; but so much fore-shortened as to preclude any idea of comparative elevation. It occurred to me at the very moment of my noticing it, that although Captain Snowdon had been much joked for having described Epping Forest as looking like a gooseberry bush, the error really existed by no means in the point of fact, but in the unfortunate selection of words in which he had chosen to express himself; for had he said that Epping Forest looked exactly like a large plantation of gooseberry trees of a gigantic size and width, he would have conveyed a very accurate idea of the fact. I particularly noticed that the forest presented to the eye a tract of dark green detached patches; where the turf (as I supposed) was visible, there seemed to be an edging of varied extent of courses of a green of a much brighter colour. All objects, of whatever kind, ceased to give any idea of comparative height, unless when seen at a considerable angle, before the balloon became in a vertical situation. I observed that white objects, as Chigwell and Ongar church, Wanstead House, and the Town Hall at Chelmsford, conveyed a much better idea of our elevation above the surface of the earth than any other objects I observed. The small rill of water that runs through the main street of Chelmsford sparkled with peculiar brilliancy; much more so indeed than either the Thames or any other water that caught the eye in the course of the voyage. Such of the roads as took the attention seemed all of one uniform colour, and that an orange-yellow; and, at the elevation at which the balloon was at the time, conveyed the idea of fine gravel walks. In one instance, in which a flock of sheep were passing in a direction from London, the dust they left behind them was very distinguishable, and this at an elevation of nearly 3000 feet. All sounds seemed to be transmitted with distinctness to us aloft, at a distance in which we could not make ourselves heard by those under us. This was to be expected, as there could be no objects near enough to the balloon to assist in reflecting the sound; whereas to those beneath us this objection did not apply; the hills and hollows all tending to influence the propagation of sound on the earth. It did not appear that any change in the state of the atmosphere affected the propagation of sound. This was contrary to my expectations. For some years since, when Colonel Beaufoy was out on a shooting party on one of the Swiss mountains, in company with the late Sir Harry Mildmay, they were enveloped in a very dense cloud; by accident Sir Harry's fowling piece went off, and the report was instantly followed by a complete roll, like that of thunder. The experiment was repeated again and again with similar results. Col. Beaufoy waited there some time, till the cloud had cleared away, and the ordinary clearness of the atmosphere was restored. He again tried the effects of the discharge of his piece; but now, no roll followed.

	Time.			Barometer.			Therm.	Kater's Hygrom.		Electro-meter.	Compass.
	Min.	Hours.		Inches and Tenths.		Feet.	Degrees.			Divergency	Course of Balloon.
Obs. 1	20	b	3	30	1	—	65	4	30	None	S W wind
2	10	b	3	26	7	3411	68	4	32	None	N E
3	5	b	3	26	7	3411	61	4	38	None	N E
4			3	26	5	3529	59	4	40	None	N E
5	5	a	3	26	3	3741	56	4	56	None	N E
6	10	a	3	27	0	3052	66	4	55	None	N E
7	15	a	3	28	2	1812	60	4	59	None	N E
8	20	a	3	27	5	2519	61	4	62	None	E
9	25	a	3	26	4	3771	59	4	65	None	Stationary
10	30	a	3	25	6	4494	56	4	67	None	Stationary
11	25	b	4	24	3	5861	54	4	75	2 Tenths	E S E
12	22	b	4	24	4	5727	54	4	85	1 Tenth	N E
13	15	b	4	26	0	4032	56	4	90	None	N
14	10	b	4	26	2	3820	56	4	90	None	E
15	7	b	4	26	0	4032	57	4	87	None	E
16	5	b	4	27	0	2986	56	4	86	None	E
17			4	27	1	2887	57	4	84	1 Tenth	N E
18	5	a	4	28	5	1501	59	4	83	2 Tenths	N E
19	10	a	4	Descended in the parish of East Thorpe, near Colchester.							

Remarks made at the different Periods of the above Observations.

Observation 1.—Made at Hackney Wick, at the moment the balloon was seen rising over the trees, and as the data from which the experiments were to be made during the voyage. The first 10 minutes were occupied in fixing the instruments, and regulating the gauge of the barometer. Mr. Sadler directed me to attend solely to the observations, and that he would himself look to the management of the balloon. Assisted in putting to rights and coiling away rope, grapnel, &c. &c. which were lying in a confused heap in the bottom of the car. Stuck the flag-staff through the back of the car, and threw off hat.

Obs. 2.—Threw out two bags of ballast, and soon after a third. A most enchanting view. Mr. Sadler pointed out some high chalk cliffs, which he said were the Nore.

Obs. 3.—The balloon had a rotatory motion, which tended to confuse any very distinct idea of situation. This motion most probably caused by some accidental twirl in the confusion in which the balloon was launched.

Obs. 4.—Sent off one of the pigeons, marked No. 7, which the instant it was at liberty flew boldly from the car in a circle, and then towards the earth at a very considerable angle. View clear and distinct.

Obs. 5.—Mr. Sadler uncorked a bottle of champaigne, and we drank the health of the Prince Regent, and afterwards that of Sir Daniel Williams, followed by all friends at Hackney. Did not perceive any alteration in the senses of taste or smell, either in the wine, or in

some sandwiches. On removing the cork, the fixed air escaped from the bottle in the form of a rather denser kind of smoke, and the wine sparkled with more vivacity than I had remarked on uncorking champaigne on other occasions. It appeared that the gas escaped with greater facility under the diminished pressure of the atmosphere at this elevation.

Obs. 6.—Observed that the least motion caused by us occasioned an amazing vibration of the quicksilver in the barometrical tube, sometimes considerably more than an inch. The compass-needle not at all altered from its horizontal position.

Obs. 7.—Mr. Sadler tried the effect of the valve, to ascertain whether it was in good order. The gas made its escape through the valve with a noise precisely similar to that of weak steam rushing through the valve of a steam boiler.

Obs. 8.—The balloon was now in the midst of a heavy shower of rain, which was presently changed into a violent hail-storm. The sound produced by the battering of the hail and rain against the upper surface of the balloon, contrasted with the general stillness that otherwise reigned around the balloon, was very striking. Threw out a board which had been taken up to answer the purpose of a table, but not used, because the weight of the load caused the angle formed by the ropes, by which the car was attached to the netting, to become more acute, and we were apprehensive that the edges of the board would cut the ropes. Threw out the wicker basket. The effect of the rain and hail on the balloon was exhibited in a copious discharge of fluid through the neck of the balloon, arising probably from a condension of the warm hydrogen gas, by the constant succession of cold fluid pouring in torrents on the upper surface of the balloon. This fluid appeared to have dissolved a portion of the varnish; for wherever it fell on the clothes or hat it left a permanent stain of a whitish-looking gummy appearance. At this time we experienced a very strong current of air or wind, not only cold and chilly to the feelings, but apparently blowing from no one particular point of the compass, as it rushed sometimes from one, at another moment from a directly opposite direction. This current of air caused the balloon to acquire a rotatory vertical motion, which made the compass traverse, as nearly as I could guess, for I did note it by the watch, once in about 20 or 30 seconds. The confusion round the car at the launching was here productive of inconvenience: for the car did not hang perfectly parallel. I was at the lowest end, and therefore found this vertical motion exceedingly inconvenient. The car was lowest on my right hand; so that it was not only lowest towards that end, but was lop-sided on my right. The motion of the balloon was from my left towards my right hand. The wind made no noise, and would not have been perceptible but for the freshness of the air on the face, and the singular motion of the balloon.

Obs. 9.—Mr. Sadler now announced to me that the balloon was passing through the clouds; and almost immediately after the clouds were seen beneath, presenting the appearance of fleecy masses. On throwing some small pieces of silver paper over the side of the car, the rapidity with which they appeared to be precipitated downwards convinced us that the balloon was rapidly ascending. The rain still continued, and the air damp and chilly to the feelings. We seemed to be station-

ary, as far as progress over the country went, but still ascending with rapidity.

Obs. 10.—At this time placed a pigeon, No. 3, on the edge of the car: the poor animal seemed excessively alarmed, standing on the edge of the car, and looking round. The earth was concealed from the view by the clouds beneath. After some little time I precipitated the pigeon gently from its perch, when it fell like a stone, until lost in the haze, which was almost in an instant. As long as it remained in sight it did not make any attempt to assist itself with its wings. The rain still came down heavily, and the fluid continued to pour down as before through the neck of the balloon.

Obs. 11.—Mr. Sadler inquired of me the heat by the thermometer, and on his receiving the answer, directed one of the bottles to be emptied of its water, for the purpose of collecting air: Mr. Sadler observing at the same time that he thought we were now at as great an elevation as we should be able to accomplish in the course of the voyage. At this elevation I could not divest myself of the idea that I heard sounds as of persons cheering from the earth, though it was not possible that it could arise from any such cause, as the balloon was still above the clouds, and we could not distinguish any thing but the dense white clouds, which now appeared precisely like a thick October fog. The air felt damp and chilly, and the rain still continued, though less violently than before. The breath was particularly visible; and from the circumstance of my having been without a hat during the whole of the excursion, it is most probable that the sounds I fancied I heard was merely a ringing in the ears, the effect of the damp. Tried the experiment repeatedly of looking towards the earth, and shouting as loudly as possible to ascertain whether the sound would be returned by echo or reflection from below; but no such effect followed. Got into a clear atmosphere, the white clouds remaining as before beneath; but on looking upwards, there was a mixture of blue and white clouds, though with a great preponderance of blue, just as is usual in a moderate clear day below.

Obs. 12.—The blue sky seemed to be of a dark and clearer blue than I had generally seen. Mr. Sadler now proposed descending into a clearer atmosphere, for the sake of getting a view of the earth, it being still concealed from the view by the dense white clouds below. This was in consequence of our noticing that 22 minutes before four the wind had reverted to the old point, and Mr. Sadler's experience led him to conclude that the balloon could not be now far distant from the sea; judging from the rate at which we had traversed over the country, as long as objects were distinguishable. Turned off a pigeon, No. 4, and it would not leave the car, but continued to look about as if frightened, and then turned its head inward, without attempting to escape. When pushed off the side of the car, it fluttered, and used the most violent exertions to regain the car; but as notwithstanding all its exertions it continued to sink rapidly below the car, it at length extended its wings, keeping them apparently immovable, and darted towards the earth, at an angle considerably inclined, with the rapidity of a hawk making his swoop. It was very remarkable that almost at the same moment a common house fly, apparently much benumbed, and scarcely competent to common exertion, crawled from beneath my seat, and without any difficulty flew with facility upwards, and settled on the lower part

of the net of the balloon, a good deal above our heads. It appears curious that so small an insect, and that too partly incapacitated, should be able to fly up to the balloon with the same rapidity as usual, when a far more powerful animal should have sunk from the car almost like a piece of wood thrown overboard. Mr. Sadler now pulled the string of the valve; the gas rushed out with somewhat less noise and violence than before, but the balloon was evidently rapidly sinking: it was a sinking perfectly sensible to the feelings, even had we not been informed by constant reference to the barometer. In ascending, there is a sensation of lifting, or more properly of pressure on the soles of the feet and the under side of the thighs; whereas, in sinking, this sensation disappears. On opening the valve there was a copious discharge of water through the balloon, as before; but it did not appear of so glutinous a nature as that before spoken of: it was probably merely the rain which had lodged on the upper side of the valve.

Obs. 13.—At this time I felt a trifling pressure in the ear, and some little deafness; but this most probably was the effect of the damp atmosphere, and being without a hat; which is by the bye a great inconvenience in such situations, on account of the ropes.

As soon as the balloon descended into a region from which the earth was perceptible, Mr. Sadler's conjectures proved just; as we saw, apparently at no great distance from us, the wide expanse of the Northern Ocean. The sensation of deafness did not go off for more than a quarter of an hour afterwards, even notwithstanding the balloon had greatly decreased in point of elevation. Until this trifling deafness, there did not appear to be the smallest difference between the intensity of sound at the greatest elevation, and at the surface of the earth. We conversed in our usual tone of voice, and any casual operation, such as drawing the cork of the champaign, &c. was heard just as usual. If any thing, the universal stillness invited rather a lower tone of voice than ordinary.

Obs. 14.—Released the pigeon, No. 1, and placed it on the edge of the car, which like the former did not attempt to escape till pushed off from the car.

Obs. 15.—Sent off the pigeon, No. 6: saw a flock of sheep very distinctly in the turnpike-road, going in a direction from London.

Obs. 16.—Sent off the pigeon, No. 5; Mr. Sadler now announced that it would be necessary to look out for some convenient spot at which to attempt a landing; saw people below at plough; called out to them; but they did not seem to be within hearing, as they did not appear to be aware of the balloon.

Obs. 17.—Mr. Sadler now cautioned me that the instruments must be removed, and directed that they should be taken into my lap. He told me likewise to be prepared, on his giving the word to heave overboard every thing that would admit of it, with a view of breaking the force of the descent. Mr. Sadler and myself were also to place our feet against the corners of the opposite seat, and then raise ourselves as much as possible with our hands by clinging to the ropes, taking care to raise our hands as high as possible above our heads.

Obs. 18.—Turned off the pigeon, No. 2: this last flew away immediately, but afterwards returned to the balloon, and flew round it several times, but without attempting to settle on the car. The live stock being thus reduced down to one, the bag that contained it was tied to one of the cords of the car, and I then hastened to cut away the ligatures by

which the different instruments were secured. In the meantime Mr. Sadler was lightening the balloon of part of a bottle of champaign, and emptied out the remaining bottle of water.

The balloon was approaching the ground fast, when Mr. Sadler gave the order to lighten, while he held the valve with both his hands to keep it open. I threw overboard the whole of the remaining ballast, and some two or three other useless articles. Mr. Sadler, when he gave the word for lightening the balloon, at the same instant let go the grapnel. The grapnel continued to drag for a few hundred yards, and I had just time enough to place myself as directed to do, with the instruments secured in the best way the hurry of the moment would admit, when the car bounded from the ground, and after passing over a hedge, and dragging a few feet more, it lay along on its side. We continued firm in our situations, without attempting to stir, until some persons, who were working close by, in a field over which the balloon had passed in its descent, came to our assistance. The balloon was soon secured, and we were released from the possibility of any farther bumping. The descent was considered by Mr. Sadler as being particularly favourable; though, to speak candidly, I formed a very decided opinion as to the uneasy situation of a descent, which Mr. Sadler, after his long experience, would deem dangerous; for the rapidity with which the car descended through the last 50 or 100 feet on this occasion, and the extraordinary sensation occasioned by the first bound, which is not unlike the dislocating shock of a galvanic battery, very much exceeded my pre-conceived idea as to the nature of a descent. The balloon grounded in a fine grass meadow, in the parish of East Thorpe, near Colchester, and was secured by the assistance of the proprietor of the farm, Mr. Thomas Ely, who was the first person that arrived to lend his friendly aid, and to whose house we, together with our apparatus, proceeded.

On questioning some of the country people who lent a hand in securing the balloon, they told us that they had heard us calling and cheering them as we passed over their heads; and that they had very distinctly seen the water that was emptied out of the bottle, which appears by the journal to have been about five minutes after four. They described it as appearing like a stream of smoke or vapour issuing from the car.

Almost as soon as the balloon touched the ground, a man brought the bottle of champaign unhurt, which had been thrown out by Mr. Sadler at an elevation of full 1000 or 1500 feet. The man said he picked it up in a ploughed field. The bottle was about two-thirds full, and loosely corked. One of the most remarkable circumstances that I observed was, that the balloon, whether in ascending or descending, provided the change in elevation was effected with rapidity, invariably formed an umbrella over our heads. The lower part, instead of hanging down, as might have been supposed on a first view of the matter, was raised upwards, and formed a concave circle over our heads; the convex side of the arch corresponding with that of the crown of the balloon. This, on reflection, seems to have been caused in both cases by the pressure of the atmosphere. In the descent, the weight below the balloon tended to compress the air against the lower side of the bag, and thus the parachute was formed by the compression of the air, because it could not escape with sufficient ease by flowing over the edges. In the ascent, on the contrary, it is probable that as the

upper side of the balloon displaced a much larger portion of air than the lower extremity, in proportion as the balloon when in the air assumes nine times in ten a pear shape, and not a sphere, unless at very considerable elevations, the air which has been so displaced by the upper part of the balloon in ascending, rushes from all directions to re-occupy the space left in the wake of the bag, and therefore it seems that the parachute thus formed in ascending is merely the effect of the eddy caused by the rapid displacement of the air.

I paid particular attention to this, because it struck me as something curious, which I had not heard mentioned by former voyagers; and I found that, in cases wherein the balloon was nearly stationary in point of vertical change of position, the lower side of the balloon hung down just as would be the case under usual circumstances.

In this voyage we experienced the inconvenience which so often occurs in aerostatic trips in insular situations; the wind being generally in such a situation, with regard to the position of London, as to carry the balloon towards the sea, and not inland. The balloon too that was used on this occasion was only 35 feet in diameter, and had been repeatedly used, and appeared to have not only suffered in the texture, but also to have gained much additional weight, from repeated varnishings.

That it was not at all calculated for the purposes of experiment seemed sufficiently proved by the exceedingly unpleasant smell of hydrogen gas which accompanied us throughout the voyage, and which it was concluded arose from its escape through the little cracks and orifices in the silk and varnish. There is no doubt that any voyage undertaken for the purpose of making experiments should be in a balloon of much greater power than that used on the 29th of August. The utmost elevation attained on this day was very little more than a mile, which is a difference of altitude not capable of exhibiting any variation from general laws sufficient to make it worth while to incur the expense of a journey. That experiments should be made correctly, if they be made at all, no one will be prepared to deny; and therefore it should be considered as a point settled, that not less than two persons should ascend together. The management of the balloon is quite sufficient to engage the attention of one person; and if any thing would tend to shake one's confidence in the extraordinary reports of some aerial travellers, it would be the very fact of their having been alone, and therefore, it is inferred, not by any means so much at their ease, or their undivided attention so much at command, as would have been requisite to read off, for example, the barometrical heights to the nicety they have pretended. It is unnecessary to point out the particular points in which we found that our observations differed from or confirmed the reports of others, as most of the excursions undertaken, either for amusement or information, are pretty generally known. It does not appear, however, that the vertical rotation experienced in the course of this voyage, when the balloon encountered the storm and current of air has been mentioned by any former travellers, with the exception of Count Zambeccari, who made an ascent with Admiral Sir Edward Vernon, at London, 23d March 1785.

CHAP. XXII.

INVENTIONS FOR THE PRESERVATION OF HUMAN LIFE.

Whatever faults may be imputed to the present age, it cannot justly be denied the praise of benevolence and humanity. Charitable institutions have arisen at every corner of our streets; schools have been established in every direction for the benefit of the children of the poor; and last, not least, the talents of ingenious men and eminent philosophers have been devoutly and successfully applied to the relief and prevention of those fatal accidents to which mankind are subject.

Among the discoveries of recent times, which next to the introduction of the cow-pock, demand the gratitude of ourselves, and of every future generation, the inventions of Mr. Greathead and Captain Manby for the preservation of shipwrecked persons—and of Professor Davy, for the prevention of those deplorable explosions which have frequently occurred in coal mines—are peculiarly worthy of commemoration, and we shall therefore present a connected epitome of these important plans. We shall begin with Mr. Greathead, who, like Captain Manby, has had the good fortune to revive the hope of shipwrecked mariners, in situations, where it has been hitherto extinct, and to snatch them from the jaws of death, in the short suspense between danger and destruction.

It appears that when a ship called the Adventure was wrecked, in 1789, on the Herd Sands, Sir Cuthbert Heron offered a reward for any seamen to go off to save the men's lives; but all refused. The greatest part of the crew of the Adventure perished within three hundred yards of the shore, and in sight of a multitude of spectators. The gentlemen of South Shields immediately met, and offered a reward to any person who would give in a plan of a boat, which should be approved, for the preservation of men's lives. Mr. Greathead gave in a plan, which met with approbation; a committee was formed, and a subscription raised for the building of a boat on that plan. After it was built, it was with some difficulty that the sailors were persuaded to go off in her, but at last they were prevailed upon by the promise of a reward, and brought the crew of a stranded vessel on shore. Since that time the boat has been readily manned, and no lives have been lost, except in the instance of the crews trusting to their own boats. Had Mr. Greathead's boat existed at the time of the wreck of the Adventure, the crew would have been saved.

The length of the boat is thirty feet; the breadth ten feet; the depth, from the top of the gunwale to the lower part of the keel in midships, three feet three inches; from the gunwale to the platform (within), two feet four inches; from the top of the stems (both ends being similar) to the horizontal line of the bottom of the keel, five feet nine inches. The keel is a plank of three inches thick, of a proportionate breadth in midships, narrowing gradually towards the ends, to the breadth of the stems at the bottom, and forming a great convexity downwards. The stems are segments of a circle, with considerable rakes. The bottom

section to the floor heads, is a curve fore and aft, with the sweep of the keel. The floor timber has a small rise, curving from the keel to the floor-heads. A bilge plank is wrought in on each side next the floor-heads with a double rabbit or groove, of a similar thickness with the keel; and, on the outside of this, are fixed two bilge-trees, corresponding nearly with the level of the keel. The ends of the bottom section form that fine kind of entrance observable in the lower part of the bow of the fishing boat, called a coble, much used in the north. From this part to the top of the stem it is more elliptical, forming a considerable projection. The sides, from the floor heads to the top of the gunwale, flaunch off on each side, in proportion to about half the breadth of the floor. The breadth is continued far forward towards the ends, leaving a sufficient length of straight side at the top. The sheer is regular along the straight side, and more elevated towards the ends. The gunwale, fixed on the outside, is three inches thick.—The sides, from the under part of the gunwale, along the whole length of the regular sheer, extending twenty-one feet six inches, are cased with layers of cork, to the depth of sixteen inches downward; and the thickness of this casing of cork being four inches, it projects at the top a little without the gunwale. The cork on the outside is secured with thin plates or slips of copper, and the boat is fastened with copper nails. The thwarts, or seats, are five in number, double banked, consequently the boat may be rowed with ten oars. The thwarts are firmly stanchioned. The side oars are short, with iron tholes and rope grommets, so that the rower can pull either way. The boat is steered with an oar at each end; and the steering oar is one third longer than the rowing oar. The platform placed at the bottom, within the boat, is horizontal, the length of the midships, and elevated at the ends, for the convenience of the steersman, to give him a greater power with the oar. The internal part of the boat next the sides, from the under part of the thwarts down to the platform, is cased with cork; the whole quantity of which, affixed to the life boat, is nearly seven hundred weight. The cork indisputably contributes much to the buoyancy of the boat, is a good defence in going alongside a vessel, and is of principal use in keeping the boat in an erect position in the sea, or rather of giving her a very lively and quick disposition to recover from any sudden cant or lurch which she may receive from the stroke of a heavy wave. But, exclusive of the cork, the admirable construction of this boat gives it a decided pre-eminence, the ends being similar, the boat can be rowed either way; and this peculiarity of form alleviates her rising over the waves. The curvature of the keel, and bottom facilitates her movement in turning, and contributes to the ease of the steerage, as a single stroke of the steering oar has an immediate effect, the boat moving as it were upon a centre. The fine entrance below is of use in dividing the waves when rowing against them; and, combined with the convexity of the bottom, and the eliptical form of the stem, admits her to rise with wonderful buoyancy in a high sea, and to launch forward with rapidity, without shipping any water, when a common boat would be in danger of being filled. The flanching, or spreading form of the boat, from the floor heads to the gunwale, gives her a considerable bearing; the continuation of the breadth, well forward, is a great support to her in the sea; and it has been found by experience, that boats of this construction are the best sea boats for rowing against turbulent waves.

The internal shallowness of the boat, from the gunwale down to the platform, the convexity of the form, and the bulk of cork within, leave a very diminished space for the water to occupy; so that the life boat, when filled with water, contains a considerable less quantity than the common boat, and is in no danger either of sinking or overturning. It may be presumed, by some, that in cases of high wind, agitated sea, and broken waves, that a boat of such a bulk could not prevail against them by the force of the oars; but the life boat, from her peculiar form, may be rowed a-head, when the attempt in other boats would fail. Boats of the common form, adapted for speed, are of course put in motion with a small power; but for want of buoyancy and bearing, are overrun by the waves and sunk, when impelled against them: and boats constructed for burthen meet with too much resistance from the wind and sea, when opposed to them, and cannot, in such cases, be rowed from the shore to a ship in distress. An idea has been entertained, that the superior advantages of the life boat are to be ascribed solely to the quantity of cork affixed. But this is a very erroneous opinion; and, I trust, has been amply refuted by the preceding observations on the supereminent construction of this boat. It must be admitted, that the application of cork to common boats would add to their buoyancy and security; and it might be an useful expedient if there were a quantity of cork on board of ships, to prepare the boats with, in cases of shipwreck, as it might be expeditiously done, in a temporary way, by means of clamps, or some other contrivance. The application of cork to some of the boats of his majesty's ships might be worthy of consideration: more particularly as an experiment might be made at a little expence, and without inconvenience to the boats; or may prevent pleasure boats from upsetting or sinking.

The life boat is kept in a boat house, and placed upon four low wheels, ready to be moved at a moment's notice. These wheels are convenient in conveying the boat along the shore to the sea; but if she had to travel upon them on a rough road, her frame would be exceedingly shaken. Besides, it has been found difficult and troublesome to replace her upon these wheels on her return from the sea. Another plan has therefore been adopted. Two wheels of nine feet diameter, with a moveable arched anis, and a pole fixed thereto for a lever, have been constructed. The boat is suspended near her centre, between the wheels under the axis; toward each extremity of which is an iron pin, with a chain attached. When the pole is elevated perpendicularly, the upper part of the axis becomes depressed, and the chains being hooked to eye-bolts on the inside of the boat, she is raised with the utmost facility, by means of the pole, which is then fastened down to the stem of the boat.

The Scarborough boat is under the direction of a committee. Twenty-four fishermen, composing two crews, are alternately employed to navigate her. A reward, in cases of shipwreck, is paid by the committee to each man actually engaged in the assistance; and it is expected that the vessel receiving assistance should contribute to defray this expence. None have hitherto refused.

It is of importance that the command of the boat should be entrusted to some steady experienced person, who is acquainted with the direction of the tides or currents as much skill may be required in rising them to the most advantage in going to a ship in distress. It should

also be recommended to keep the head of the boat to the sea, as much as circumstances will admit; and to give her an accelerated velocity to meet the wave. Much caution is necessary in approaching a wreck, on account of the strong reflux of the waves, which is sometimes attended with great danger. In a general way, it is safest to go on the lee-quarter; but this depends upon the position of the vessel; and the master of the boat should exercise his skill in placing her in the most convenient situation. The boatmen should practise themselves in the use of the boat, that they may be the better acquainted with her movements; and they should at all times be strictly obedient to the directions of the person who is appointed to the command.

The great ingenuity which has been displayed in the construction of the life boat, leaves scarcely any room for improvement: but some have supposed, that a boat of twenty-five feet in length, with a proportionate breadth, would answer every purpose of a larger one. A boat of these dimensions would certainly be lighter, and less expensive; but whether she would be equally safe and steady in a high sea, I cannot take upon myself to determine.

In the year 1791, the crew of a brig, belonging to Sunderland, and laden from the westward, were preserved by this life boat, the vessel at the same time breaking to pieces by the force of the sea.

On January 1st, 1795, the ship Parthenius, of Newcastle, was driven on the Herd Sand, and the life boat went to her assistance, when the sea breaking over the ship as the boat was ranging along-side, the boat was so violently shaken that her bottom was actually hanging loose; under these circumstances, she was three times off to the ship, without being affected by the water in her.

The ship Peggy being also on the Herd Sand, the life boat went off, and brought the crew on shore, when the plug in her bottom had been accidentally left out; though she filled with water in consequence, yet she effected the purpose in that situation.

In the latter part of the year 1796, a sloop, belonging to Mr Brymer, from Scotland, laden with bale goods, was wrecked on the Herd Sands; the crew and passengers were taken out by the life boat; the vessel went to pieces at the time the boat was employed; the goods were scattered on the sand, and part of them lost.

In the same year, a vessel, named the Countess of Errol, was driven on the Herd Sand, and the crew saved by the life boat.

October 15th, 1797, the sloop, called Fruit of Friends, from Leith, coming to South Shields, was driven on the Herd Sand. One part of the passengers, in attempting to come on shore in the ship's boat, was unfortunately drowned; the other part was brought on shore safe by the life boat.

The account of Captain William Carter, of Newcastle, states, that on the 28th of November 1797, the ship Planter, of London, was driven on shore near Tynemouth-bar, by the violence of a gale; the life boat came out, and took fifteen persons from the ship, which the boat had scarcely quitted before the ship went to pieces; that, without the boat, they must all have inevitably perished, as the wreck came on shore soon after the life boat. He conceived that no boat, of a common construction, could have given relief at that time. The ships, Gateshead and Mary of Newcastle, the Beaver of North Shields, and a sloop, were in the same situation with the Planter. The crew of the

Gateshead, nine in number, took to their own boat, which sunk, and seven of them were lost; the other two saved themselves by ropes thrown from the Mary. After the life boat had landed the crew of the Planter, she went off successively to the other vessels, and brought the whole of their crews safe to shore, together with the two persons who had escaped from the boat of the Gateshead.

Mr. Carter adds, that he has seen the life boat go to the assistance of other vessels, at different times, and that she ever succeeded in bringing the crews on shore; that he had several times observed her to come on shore full of water, and always safe.

An account of the Northumberland Life Boat.

The Northumberland life boat, so called from its being built at the expence of his Grace the Duke of Northumberland, and presented by him to North Shields, was first employed in November 1798, when she went off to the relief of the sloop Edinburgh, of Kincardine, which was seen to go on the Herd Sands, about a mile and a half from the shore. Ralph Hillery, one of the seamen who went out in the life boat to her assistance, relates, that she was brought to an anchor before the life boat got to her; that the ship continued to strike the ground so heavily, that she would not have held together ten minutes longer, had not the life boat arrived; they made her cut her cable, and then took seven men out of her, and brought them on shore; that the sea was at that time so monstrously high, that no other boat whatever could have lived in it. He stated, that in the event of the life boat filling with water, she would continue still upright, and would not founder, as boats of a common construction do; that he has seen her go off scores of times, and never saw her fail in bringing off such of the crews as staid by their ships.

It also saved (as appears from other accounts) the crew of the brig Clio, of Sunderland, when she struck upon the rocks called the Black Middens, on the north side of the entrance of Tynemouth Haven.

October 25th, 1799, the ship Quintilian, from St. Petersburgh, drove on the Herd Sand, from the force of the sea, wind at N. E. knocked her rudder off, and was much damaged; but the crew were brought on shore by the life boat. The great utility of this life boat is also confirmed by many other recent circumstances: one among which is that of the ship Sally, of Sunderland, which, in taking the harbour of Tynemouth, on December 25th, 1801, at night, struck on the bar: the crew were brought on shore by the life boat, but the ship was driven among the rocks.

On the 22d of January 1802, in a heavy gale of wind, from the N. N. W. the ship Thomas and Alice, in attempting the harbour of South Shields, was driven on the Herd Sand: the Northumberland life boat went to her assistance; took, as was supposed, all the people out, and pulled away from the ship to make the harbour, when they were waved to return by a man who had been below deck. On taking this man out they encountered a violent gust of wind, under the quarter of the ship; the ship at the same time drove among the breakers; and, entangling the boat with her, broke most of the oars on that side of the boat next the ship, and filled the boat with water. By the shock several of the oars were knocked out of the hands of the rowers, and that of the steersman. In this situation, the steersman quickly replaced

his oar from one of those left in the boat, and swept the boat before the sea, filled with water inside as high as the midship gunwale: the boat was steered in this situation, before the wind and sea, a distance far exceeding a mile, and landed twenty-one men, including the boat's crew, without any accident, but being wet.

Account of the Scarborough Life Boat, by Thomas Hinderwell.

Sir—The life boat at Scarborough, which was built without the least deviation from the model and the plan which you sent here at my request, has even exceeded the most sanguine expectations; and I have now received experimental conviction of its great utility in cases of shipwreck, and of its perfect safety in the most agitated sea. Local prejudices will ever exist against novel inventions, however excellent may be the principles of their construction; and there were some at this place, who disputed the performance of the life boat, until a circumstance lately happened, which brought it to the test of experience, and removed every shadow of objection, even from the most prejudiced minds.

On Monday, the 2d of November, we were visited with a most tremendous storm from the eastward, and I scarcely ever remember seeing a more mountainous sea. The Aurora, of Newcastle, in approaching the harbour, was driven ashore to the southward; and, as she was in the most imminent danger, the life boat was immediately launched to her assistance. The place where the ship lay was exposed to the whole force of the sea, and she was surrounded with broken water, which dashed over the decks with considerable violence. In such a perilous situation the life boat adventured, and proceeded through the breach of the sea, rising on the summit of the waves, without shipping any water, except a little from the spray. On going upon the lee-quarter of the vessel, they were endangered by the main-boom, which had broken loose, and was driving about with great force, This compelled them to go along side, and they instantly took out four of the crew; but the sea which broke over the decks having nearly filled the boat with water, they were induced to put off for a moment, when seeing three boys (the remainder of the crew) clinging to the rigging, and in danger of perishing, they immediately returned, and took them into the boat, and brought the whole to land in safety. By means of the life boat, built from your plan, and the exertions of the boatmen, seven men and boys were thus saved to their country and their friends, and preserved from the inevitable destruction which otherwise awaited them. The boat was not in the least affected by the water which broke into her when alongside the vessel; and, indeed, the boatmen thought it rendered her more steady in the sea. I must also add, that it was the general opinion, that no other boat of the common construction could have possibly performed this service; and the fishermen, though very adventurous, declared they would not have made the attempt in their own boats.

We have appointed a crew of fishermen to manage the boat, under the direction of the committee, and the men are so much satisfied with the performance of the boat, and so confident in her safety, that they are emboldened to adventure upon the most dangerous occasion. I have been thus circumstantial, in order to shew the great utility of the life boat; and, I should think, it would be rendering an essential ser-

vice to the community, if any recommendation of mine should contribute to bring this valuable invention into more general use.—I remain, Sir, &c.

Captain Manby's Apparatus.

Those who have had the opportunity of seeing the pictures of desolation realized on the eastern and north-eastern coasts of our island, and who have beheld the dreadful train of consequences that ensue;—the agonizing cries of the sailors;—the torturing suspense of the by-standers on the beach;—the dead bodies washed on shore;—and too often the lamentations of the wife or child over the body of an honest and industrious parent;—can best appreciate the merits of Captain Manby. He was a captain of engineers, and held the station of barrack-master at Yarmouth, on the coast of Norfolk, in the year 1807. It is well known, that the coast for several leagues N. of that port, and, indeed, the whole eastern coast of our island, is peculiarly dangerous to navigators in the winter months, and totally unprovided with secure harbours. The consequence is, that many ships are unavoidably driven ashore, or rather upon the shoals of the coast, which will seldom permit the approach of a wreck within less than 100 yards of the land. Frequent are the instances in which vessels thus fixed within sight of their owners, and crews, whose cries were within hearing of their friends and relations, have been beaten to pieces by the waves, and engulphed in the deep, without the possibility of affording any assistance, from the want of means to establish a communication either by a boat, or by a rope, with the object in danger. It is obvious, that if communication, even by a slender packthread, can once be established between a stranded vessel and persons on shore, a rope may first be run out, and then a cable, by means of which the crew, and the most valuable parts of the cargo, may be successively drawn to the land. The following extracts from the preface give an account of the events which first drew Captain Manby's attention to the subject, and of the difficulties which he had to surmount; the perusal of them will render the description of the means, to which he had recourse, both more intelligible and more interesting.

" The dreadful events of the 18th of February 1807, when his majesty's gun-brig Snipe was driven on shore near the Haven's mouth at Yarmouth, first made an impression on my mind, which has never been effaced. At the close of that melancholy scene, after several hours of fruitless attempt to save the crew, upwards of sixty persons were lost, though not more than fifty yards from the shore, and this wholly owing to the impossibility of conveying a rope to their assistance. At that crisis a ray of hope beamed upon me, and I resolved immediately to devote my mind to the discovery of some means for affording relief in cases of similar distress and difficulty. It is matter of no small consolation, when I reflect that my efforts were soon crowned with the happiest success, and have been already instrumental to the preservation of ninety souls from a watery grave, of which seventy-seven were my countrymen, and thirteen unfortunate Hollanders.

" In the prosecution of my object considerable difficulty presented itself, viz. in the case of vessels grounding on a bar, when running for a harbour, as their only chance of safety; the broken water, by giving no resistance to the blade of the oar, prevents a boat from pulling up to the ship's aid, though within ten or twenty yards of her. My attention

became here engaged in the construction of a small piece of ordnance for the purpose of projecting a rope from the boat so as to communicate in such circumstances with the ship. A small portable mortar was also essential, the better to ensure a prompt and effectual communication, at a period when each successive instant was big with the fate of an entire ship's company.

"The dreadful event also of a Swedish brig, called the Wandering Main, driven on shore at Hasbro', in the night of the 5th of January 1809, imprinted on my feelings the necessity of contriving a method of affording the same assistance at the more awful hour of night, when darkness doubles the danger, and baffles even the experienced navigator. It was on this lamented occasion, a dark and dismal night, when objects were scarcely discernible, that numerous unavailing attempts were made to project a rope to the vessel by the means successfully used in the day; but its flight could not be observed, either by the persons on shore or those on board, and seven long and anxious hours elapsed before the light of day favoured the endeavours to effect the much-desired communication; when, at the very instant the cot reached the vessel, she went to pieces, and every soul on board perished!"

We may add also, that in one day only, viz. the 10th Nov. 1810, the crews of sixty-five vessels, wrecked on our N. E. coasts, entirely perished within one hundred yards of the shore. The number of souls was estimated at 500;—and it is fair to presume, from the result of experience, that if the apparatus of which we are about to give a short description had been within reach, 460 of these lives might have been saved. On these data some probable estimate may be formed of the annual saving of lives to the nation, from the general adoption of the apparatus on the coasts of our islands.

We have already stated, that the object in view was to discover some certain means of projecting a rope in boisterous weather from the land to a ship stranded on a shoal at some distance. The active and philanthropic mind of Captain Manby was not tardy in pointing out a probable method. It struck him that a cannon shot affixed to a rope, and projected from a piece of ordnance over a stranded vessel, was a practicable mode of establishing the communication. But to reduce it to practice was found to be attended with much greater difficulty than the simplicity of the object seemed at first sight to promise.

In the first place, the faking or manner of laying the rope so as to unfold itself with the rapidity equal to the flight of a shell from a mortar, without breaking by sudden jerks at each returning fold, and without entanglement from the effect of uneven ground and boisterous winds, was no easy task. But it was at length attained by adopting what is called a French faking, in folds of the length of two yards; and by laying the rope in a flat basket always kept ready, with the rope in order, in a secure place; so that it could be transported at a moment's notice to the situation required, and laid upon rocks and uneven ground, even in the most boisterous weather, without fear of disarrangement.

The next difficulty consisted in the means of connecting the rope with a shot, so as to resist the inflammation of gunpowder in that part of it which must necessarily occupy the interior of the mortar. Chains in every variety of form and strength universally broke from the sudden jerks or play to which they were liable, "which proved, that not only

an elastic, but a more connected body was necessary." "At length," says Captain Manby, "some stout platted hide, woven extremely close to the eye of the shot to prevent the slightest play, extending about two feet beyond the muzzle of the piece, and with a loop at the end to receive the rope, happily effected it."

This apparatus projected over a vessel stranded on a lee-shore from a small howitzer, so light as to be easily conveyed from one part of the coast to another, affords a certain means of saving the lives of the crew in the day-time, and when from cold and fatigue they are not disabled from seizing and fastening the rope, and in other respects, joining their own exertions to those of their friends on shore. The following extract from an account of experiments made before some colonels and field-officers of artillery, shew the celerity with which the service may be performed.

"A person is completely equipped with every necessary apparatus to effect communication with a vessel driven on a lee-shore, A man mounted on horseback was exhibited, accoutred with a deal frame, containing 200 yards of log line ready coiled for service, which was slung as a knapsack; with a brass howitzer of a three-pounder bore on its carriage, and two rounds of ammunition, the whole weighing 62 pounds, strapped on the fore part of the saddle. The person thus equipped is supposed to be enabled to travel with expedition to the aid of ships in danger of being wrecked on parts of the coast intermediate to the mortar stations; and with this small apparatus, the log line is to be projected over the vessel in distress, from which a rope should be attached to it to haul the crew on shore. Captain Manby caused the howitzer to be dismounted from the horse, and in a few minutes fired it, when the shot was thrown, with the line attached, to the distance of 143 yards.

"At a subseqnent trial the horseman, fully equipped, travelled a mile and a third; the howitzer was dismounted, and the line projected 153 yards, in six-minutes."

In order more fully to explain the mode of operation, we lay before our readers a sketch of the apparatus in full activity.

Such is the simple but efficacious nature of Captain Manby's first invention; and a few practical experiments soon ascertained the allowance to be made in pointing the mortar to windward of the object over which the rope is to fall, in order to obviate the effect of a strong wind, which would, of course, carry it considerably to leeward.

Experience also proved, that the mortar should be laid at a low elevation, in order to ensure the certainty of the rope's falling on the weathermost part of the rigging.

This original invention, however, was obviously capable of many improvements. The first of which was to afford assistance to vessels whose crews, either from their being lashed to the rigging, or from extreme cold and fatigue, are incapable of assisting to secure the rope to the wreck when projected over it from the mortar. This was attained by adding a quadruple barb to the shot, by means of which, when the rope is hauled tight by the people on shore, one end is firmly secured on some part of the rigging or wreck, and a boat can of course be hauled to the relief of the crew, without any assistance on their part.

The following is one of the many certificates of the practical benefits that have resulted from this improvement:

"We, the crew of the brig, Nancy, of Sunderland, do hereby certify, that we were on board the said vessel, when she was stranded on the beach of Yarmouth, on Friday morning the 15th of December 1809, and compelled to secure ourselves in the rigging, to prevent being swept away, the sea running so high over the vessel. And we do further declare and certify, that Captain Manby firing a rope with a hooked shot securely holding on the wreck, enabled a boat to be hauled from the shore over the surf to our relief otherwise we must inevitably have perished." Signed by six persons.

Ships are also stranded by night more frequently than by day, and generally in dark and boisterous nights; and to wait till day-light for the application of this apparatus might of course eventually preclude all its benefits.

The weather, also, upon an open coast, during a storm, is seldom favourable for the inflammation of gunpowder; and some attempts to save the lives of the shipwrecked had actually failed from the wetness of the powder and the difficulty of keeping a portfire burning. Captain Manby at first attempted to obviate this last inconvenience by the use of a pistol lock and short barrel; but he found the following ingenious contrivance by far the most efficacious mode of securing a discharge: A short funnel-shaped tube of common writing paper is filled with a preparation of

gunpowder, and stuck into the touch-hole of the mortar; and Captain Manby carries in his pocket a small phial of liquid, with which he wets the end of his finger, and applying it to the gunpowder tube, produces instant inflammation and a discharge of the mortar, even in the wettest weather. We believe that there are several preparations known to chemists which will produce this effect; but this by no means detracts from the merit of Captain Manby's application of one of them to this specific and beneficial purpose, or weakens his claim to the merit of any advantage which the general service may derive from discharging battering artillery in the same manner. It is not the mere inventor of an insulated fact, converted to no purpose of practical utility, that has a just claim upon the gratitude of mankind, but he who converts an object, but little known or little used, to new purposes—and his claim is great, exactly in proportion to the extent of the advantages derivable from the nature of those purposes.

The preservation of human life from sudden and violent termination is an object of the highest importance, both with a view to policy and humanity. But when the exertions for such a purpose are occupied on behalf of our fellow countrymen engaged in the sea service, of men who expose their lives to double risk, to the storm and to the battle, for the comfort and safety of those who sit at home—they are doubtless at least doubly interesting. And though we are far from wishing to derogate from the portion of credit due to the prosecution of science for any facilities that may be offered, we must strenuously insist that the man who first converts scientific discoveries to noble purposes of practical utility, not previously in the contemplation of philosophers, has a just and fair claim to the title of an original inventor.

It now remains that we explain to our readers the ingenious method by which Captain Manby contrived to extend the assistance (afforded by his first invention to ships stranded in the day-time), to those wrecked even in the darkest nights. The requisite objects were,

1. First, to devise the means of discovering precisely where the distressed vessel lies, when the crew are not able to make their exact situation known by luminous signals.

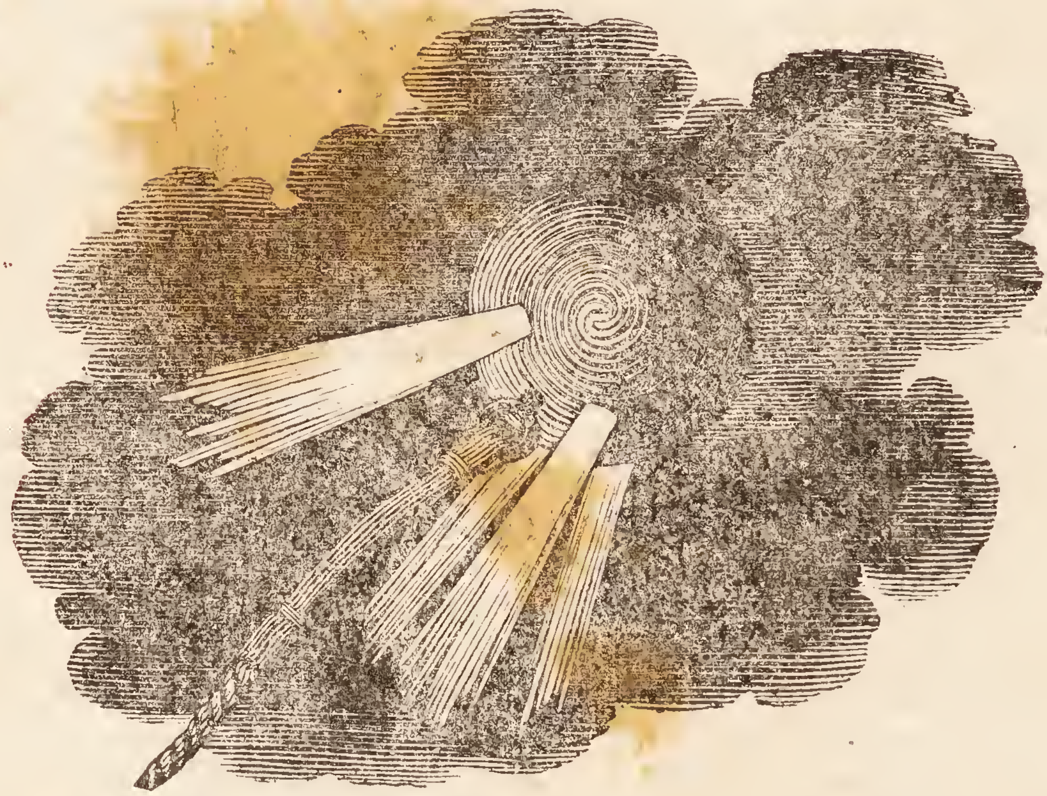
2. Secondly, to discover a method of laying the mortar for the object with as much accuracy as in the light.

3. Thirdly, to render the flight of the rope perfectly distinguishable to those who project it, and to the crew on board the vessel, so that they cannot fail of seeing on what part of the rigging it lodges, and consequently may have no difficulty in securing it.

To attain the first object, a fire ball is used, such as is often thrown up in the attack and defence of fortified places to discover the situation of an enemy by night—and such as was in fact used by the French at the siege of Badajoz to discover the exact situation of our storming parties in front of the breaches. It consists of a hollow ball of pasteboard, having a hole at top containing a fuse, and filled with about fifty luminous balls of star composition, and a sufficient quantity of gunpowder to burst the ball and inflame the stars. The fuse is graduated so as to set fire to the bursting powder at the height of 300 yards. On the stars being released, they continue their splendour while falling for near one minute, and strongly illumine every surrounding object: ample time is therefore allowed to discover the situation of the distressed vessel.

During the period of the light, a board, with two upright sticks at each end (painted white to render them more discernible in the dark), is pointed towards the vessel, so that the two white sticks shall meet in a direct line with it, the wreck being a fixed object. This will obviously afford an undeviating rule by which to lay the mortar, making an allowance, as by daylight, for wind, &c. Thus the second object is attained.

For the third, a shell (instead of a shot) is affixed to the rope, having four holes in it to receive fuzes, and the body of the shell is filled with the fiercest and most glaring composition, which when inflamed, displays so splendid an illumination of the rope, that its flight cannot be mistaken.



Report of experiments made thereon, before a committee of colonels and field-officers of the royal artillery at Woolwich, on the 3d of May 1809, by order of the honourable Board of Ordnance.

"*Royal Arsenal, Woolwich, May 3,* 1809.

"Sir,—I request you will inform the master general and the right honourable board, that in obedience to their orders, communicated in your letter of the 28th ultimo, the committee of colonels and field officers assembled on the following day, to witness the further experiments proposed by Captain Manby, with a view of obtaining a communication from the land with stranded vessels.

"On this occasion Captain Manby exhibited his contrivance for ascertaining the position of a ship stranded during the night-time, by projecting light-balls into the air, from a mortar at a high elevation, by which means obtaining a momentary view of the object, its situation is instantly and determinately marked, by placing two upright sticks, fixed on a short plank, which can be moved with the greatest facility in the exact direction, and by which the mortar can be laid with precision, in the usual manner.

"Captain Manby then exhibited a contrivance to insure the firing of

the mortar in wet or stormy weather, by means of a short pistol, the lock of which is so covered by a tin box as to exclude the effects of the wind or rain on the priming.

" The next experiment was to prove the practicability of throwing a life rope attached to a shot from a 12-pounder carronade, and the application of a shell with several fuzes, instead of a shot for the same purpose, at night, so that the crew on board the stranded vessel, by the brilliant light of the fuzes, could not fail to see the projection of the rope to their assistance.

" I am happy to report to his lordship and honourable board, that Captain Manby's experiments were perfectly satisfactory to the committee, and they have no doubt of their successful application to the noble purpose he has in view.

" I have the honour to be, &c.

" To R. Crew, Esq. VAUGHAN LLOYD,
Secretary to the Ordnance, Col. Com. Lieut. Gen."

Such are the most prominent and interesting facts relating to Captain Manby's discoveries for the preservation of shipwrecked seamen. There are many minor points, respecting the mode of bringing the sick on shore, of carrying a boat over a surf, to reach a vessel stranded without a bar, &c. &c. to which we have not time to refer, but which are described and illustrated by wood cuts in his admirable work, intitled, " An Essay on the Preservation of Shipwrecked Persons." Among these we are particularly struck with his simple method of converting any common boat into a life-boat, at an expence of about *3l.* by merely lashing within the gunwhale six or seven empty and air-tight water casks, or oil casks if they are within reach—a plan that has been found so efficacious in giving buoyancy, that sailors who have tried it have no hesitation in putting to sea in such a boat with a hole bored through her bottom.

The whole expence of the apparatus invented by Captain Manby, we understand, amounts to about *10l.*; and we have no hesitation in delivering our opinion, that sets should be deposited, at the public expence, at intervals of about ten or a dozen miles, along all the dangerous coasts of the United Kingdom; that is, along all those coasts where, from the flatness of the shore, vessels driven upon it will strike within two hundred yards of the land. Many parts of England, Scotland, and Ireland come under this description. And if, in addition to this precaution, the activity of the fishermen and villagers on the coasts was stimulated by a bounty, in the way of head-money, for the life of each mariner saved out of a wreck by this process, at least in every case of difficulty and hazard, when the people concerned risk their own lives in the attempt, the provision would be a wise one, and worthy of the justice and humanity of a British board of admiralty.

It is highly creditable to Captain Manby, that he had no sooner completed his invention and carried it into operation on the coast of Norfolk, than he addressed a letter to the magistrates of that county, exhorting them by very forcible reasons to institute a " Society for the relief of shipwrecked mariners;" and specifically for providing them with such clothing and necessaries as may in different cases be required, and for assisting them to their homes. It is no less creditable to the magistracy of that distinguished county, that they immediately answered the

call, and instituted a society for the purposes proposed. Captain Manby calls upon the other maritime counties to follow the example, in the following words, which do equal credit to his feelings and to his judgment:

"I cannot, however, feel satisfied, and leave the work of humanity half perfected. That the shipwrecked mariner, if preserved, is brought on shore, worn out with bodily fatigue, and mental horror and agitation, with limbs benumbed and swollen with wet and cold; destitute, most probably, of either linen or clothes, except those on his back, wet, drenched, and dripping; that he preserves neither money nor means to relieve himself, nor to procure those necessaries and comforts, which cold, hunger, and nakedness claim; that he, perhaps, is many miles distant from his family and friends, or from a port whence he might get a passage to them; these, and such like circumstances of distress, which have been realised in many instances of shipwreck, wherein I have been concerned, induce me to make one effort more in behalf of such sufferers, by recommending to the consideration of every county where calamities of this kind are frequently occurring, whether an alleviation of the hardships to which this valuable order of men are exposed might not be purchased at an easy rate; whether the injury of their health might not be easily repaired, or provided against, comfort administered, and themselves be helped on their way to their place of abode."

Sir Humphrey Davy's Discoveries.

We shall now proceed to the important and unparalleled discoveries of Sir Humphrey Davy.

The triumph of persevering science over the laws and operations of nature has never been more proudly displayed than in the system of preservation, so happily deduced from a deep consideration of the subject, and a perfect acquaintance with the principles of chemistry. The value of the discovery to mankind surpasses calculation. For the last two hundred years, Northumberland has been the scene of sudden death, lamentation, and dismay. Scarcely a year elapsed without some fatal explosion of the fire-damp, which destroyed a considerable number of men, and diffused among their families poverty and distress. Various efforts had been made to remedy the evil, but in vain, and the occurrence of the following horrible accidents at length induced the proprietors of coal-mines to request the advice of Sir Humphrey Davy.

Felling is a manor about a mile and a half east of Gateshead. It contains several strata of coal, the uppermost of which were extensively wrought in the beginning of the last century. The stratum called the High-main was won in 1779, and continued to be wrought till the 19th January 1811, when it was entirely excavated. The present colliery is in the seam called the Low-main. It commenced in October 1810, and was at full work in May 1812. This mine was considered by the workmen as a model of perfection in the purity of its air, and orderly arrangements—its inclined plane was saving the daily expence of at least 13 horses—the concern wore the features of the greatest possible prosperity, and no accident, except a trifling explosion of fire-damp, slightly burning two or three workmen, had occurred. Two *shifts* or sets of men were constantly employed, except on Sundays. Twenty-five acres of coal had been excavated. The first shift entered

the mine at four o'clock A. M. and were relieved at their working posts by the next at 11 o'clock in the morning. The establishment it employed under-ground consisted of about 128 persons, who, in the fortnight from the 11th to the 25th of May 1812, wrought 624 scores of coal, equal to 1300 Newcastle chaldrons, or 2455 London chaldrons. About half past eleven o'clock on the morning of the 25th of May 1812, the neighbouring villages were alarmed by a tremendous explosion in this colliery. The subterraneous fire broke forth with two heavy discharges from the *John*, which were, almost instantaneously, followed by one from the *William*. A slight trembling, as from an earthquake, was felt for about half a mile around the workings; and the noise of the explosion, though dull, was heard to three or four miles distance, and much resembled an unsteady fire of infantry.

Immense quantities of dust and small coal accompanied these blasts, and rose high into the air, in the form of an inverted cone. The heaviest part of the ejected matter, such as corves, pieces of wood, and small coal, fell near the pits; but the dust, borne away by a strong west wind, fell in a continued shower from the pit to the distance of a mile and a half. As soon as the explosion was heard, the wives and children of the workmen ran to the working-pit. Wildness and terror were pictured in every countenance. The crowd from all sides soon collected to the number of several hundreds, some crying out for a husband, others for a parent or a son, and all deeply affected with a mixture of horror, anxiety, and grief. The machine being rendered useless by the eruption, the rope of the gin was sent down the pit with all expedition. In the absence of horses, a number of men, whom the wish to be instrumental in rescuing their neighbours from their perilous situation, seemed to supply with strength proportionate to the urgency of the occasion, put their shoulders to the starts or shafts of the gin, and wrought it with astonishing expedition. By twelve o'clock, 32 persons, all that survived this dreadful calamity, were brought to daylight. The dead bodies of two boys, who were miserably scorched and shattered, were also brought up at this time: three boys, out of the 32 who escaped alive, died within a few hours after the accident. Only 29 persons were, therefore, left to relate what they observed of the appearances and effects of this subterraneous thundering: 121 were in the mine when it happened, and 87 remained in the workings. Eight persons came up at different intervals, a short time before the explosion. They who had their friends restored, hastened with them from the dismal scene, and seemed for a while to suffer as much from the excess of joy as they had lately done from grief; and they who were yet held in doubt concerning the fate of their relations and friends, filled the air with shrieks and howlings; went about wringing their hands; and threw their bodies into the most frantic and extravagant gestures. The persons who now remained in the mine, had all been employed in the workings to which the plane-board was the general avenue, and as none had escaped by that way, the apprehension for their safety began to strengthen every moment. At a quarter after twelve o'clock, Messrs. Straker, Anderson, Haswell, Rogers, Wilson, Pearson, Anderson, Menham, and Greener, therefore descended the John, in expectation of meeting with some of them alive. As the fire-damp would have instantly ignited at candles, they lighted their way by *steel-mills*, small machines which give light by turning a plain thin cylinder of steel

against a piece of flint. Knowing that a great number of the workmen would be at the crane when the explosion happened, they attempted to reach it by the plane-board; but their progress was intercepted at the second pillar by the prevalence of choak-damp: the noxious fluid filled the board between the roof and the thill; and the sparks from the steel fell into it like dark drops of blood. Being, therefore, deprived of light, and nearly poisoned for want of atmospheric air, they retraced their steps to the shaft, and with similar success attempted to pass up the narrow boards: in these they were stopped at the sixth pillar by a thick smoke, which stood like a wall the whole height of the board. Here their flint-mills were not only rendered useless, and respiration became extremely difficult, but the probability of their ever reaching the places where they expected to meet with those they were in search of, or of finding any of them alive, was entirely done away. To the hopelessness of success in their enterprize should also be added, their certainty of the mine being on fire, and the probability of a second explosion at every moment occurring and burying them in its ruins.

At two o'clock Mr. Straker and Mr. Anderson had just ascended the John, and were gone to examine the appearance of the air issuing from the William. Menham, Greener, and Rogers, had also ascended. Two of the party were at this moment in the shaft, and the other two remained below, when a second explosion, much less severe than the first, excited more frightful expressions of grief and terror amongst the relatives of the persons still in the mine. Rogers and Wilson, the persons in the shaft, experienced little inconvenience by the eruption: they felt an unusual heat, but it had no effect in lifting up their bodies, or otherwise destroying the uniformity of the motion of their ascent. Haswell and H. Anderson, hearing its distant growlings, laid themselves down at full length on their faces, and in this posture, by keeping firm hold of a strong wooden prop, placed near the shaft, to support the roof of the mine, experienced no other inconvenience from the blast, than its lifting up their legs and poising their bodies in various directions, in the manner that the waves heave and toss a buoy at sea. As soon as the atmospheric current returned down the shaft, they were drawn to bank. This expedient of lying down and suffering the fury of the blast to roll over them, is mentioned in the Life of Lord Keeper North, under the year 1676. It is most efficacious where the mine is wet, for atmospheric air always accompanies running water; but the warning of a blast being usually sudden, it requires a degree of experience and coolness, not commonly united, to exercise any precaution against it. The miner knowing its irresistible power, instantly sees the inefficacy of every attempt to escape, and, like a physician attacked by some incurable complaint, and, conscious that his art is unequal to its cure, makes no struggle to save his life. As each of the party came up, he was surrounded by a group of anxious inquirers. All their reports were equally hopeless; and the second explosion so strongly corroborated their account of the impure state of the mine, that their assertions for the present seemed to be credited. But this impression was only momentary. On recollection, they remembered that persons had survived similar accidents, and when the mine was opened, been found alive. Three had been shut up during 40 days in a pit near Byker, and all that period had subsisted on candles and horse beans. The proposition to exclude the atmospheric air from the mine, in order to extinguish the fire, was there-

fore received with the cries of "*Murder*," and with a determination of opposing the proceeding. Many of the widows continued about the mouth of the John pit during the whole of Monday night, with the hope of hearing the voice of a husband or a son calling for assistance. On Tuesday the 26th of May, the natural propensity of the human mind to be gratified with spectacles of horror was strongly exemplified. An immense crowd of colliers from various parts, but especially from the banks of the river Wear, assembled round the pits, and were profuse in reproaches on the persons concerned in the mine, for want of exertion to recover the men. Every one had some example to relate of successful attempts in cases of this kind,—all were large in their professions of readiness to give assistance; but none were found to enter the inflammable jaws of the mine. Their reasonings and assertions seemed indeed to be a mixture of those prejudices and conceits which cleave to workmen whom experience has afforded a partial insight into the nature and peculiarities of their profession, and not to be grounded on any memory of facts, or to result from a knowledge of the connection between causes and effects; and on this account, as soon as the leaders of the outcry could be brought to listen with patience to a relation of the appearances that attended this accident, and to hear the reasons assigned for the conclusion that the mine was on fire, and that the persons remaining in it were dead, they seemed to allow the impracticability of reaching the bodies of the sufferers till the fire was extinguished, and consequently the necessity of smothering it out by excluding atmospheric air from the mine. On Wednesday the 27th of May, at the clamorous solicitation of the people, Mr. Straker and the overman again descended the John pit, in order to ascertain the state of the air in the workings. Immediately under the shaft they found a mangled horse, in which they supposed they perceived some signs of life; but they had only advanced about six or eight yards, before the sparks of the flint were extinguished in the choak-damp, and Haswell, who played the mill, began to show the effects of the carbonic poison, by faultering in his steps. Mr. Straker therefore laid hold of him, and supported him to the shaft. As the baneful vapours had now taken possession of the whole of the mine, and they found it difficult to breathe even in the course of the full current of the atmospheric air, they immediately ascended. But the afflicted creatures, still clinging to hope, disbelieved their report. Wishful, therefore, to give as ample satisfaction as possible to the unhappy women, Mr. Anderson and James Turnbull (a hewer of the colliery, who had escaped the blast) again went down. At 30 fathoms from the bottom they found the air exceedingly warm: to exist without apoplectic symptoms for more than a few yards round the bottom of the shaft, was found impossible, and even there the air was so contaminated as to be nearly irrespirable. When they ascended, their clothes emitted a smell somewhat resembling the waters of Gilsland and Harrowgate, but more particularly allied to that of the turpentine distilled from coal tar. The report of these last adventurers partly succeeded in convincing the people that there was no possibility of any of their friends being found alive. Some, indeed, went away silent, but not satisfied; others with pitiable importunity besought that measures to recover their friends might even yet be adopted and persevered in; and many, as if grief and rage had some necessary connection, went about loading the conductors of the mine with execrations,

and threatening revenge. Some were even heard to say they could have borne their loss with fortitude had none of the workmen survived the calamity; they could have been consoled had all their neighbours been rendered as miserable and destitute as themselves! From such a multitude of distracted women, unanimity of sentiment could not be expected—no scheme of proceedings could be invented fortunate enough to meet with the approbation of them all. In the evening of this day it was, therefore, resolved to exclude the atmospheric air from entering the workings, in order to extinguish the fire which the explosion had kindled in the mine, and of which the smoke ascending the William pit was a sure indication. This shaft was accordingly filled with clay about seven feet above the ingate or entrance from the shaft into the drift; and the John Pit mouth was covered over with loose planks.

Many idle tales were circulated through the country concerning several of the men finding their way to the shafts, and being recovered. Their number was circumstantially told—how they subsisted on candles, oats, and beans—how they heard the persons who visited the mine on the day of the accident, and the Wednesday following, but were too feeble to speak sufficiently loud to make themselves heard. Some conjurer too, it was said, had set his spells and divinations to work, and penetrated the whole secrets of the mine. He had discovered one famishing group receiving drops of water from the roof of the mine—another eating their shoes and clothes, and other such pictures of misery. These inventions were carefully related to the widows, and answered the purpose of every day harrowing up their sorrows afresh. Indeed, it seemed the chief employment of some, to make a kind of insane sport of their own and their neighbour's calamity.

The morning of Wednesday the 8th of July, being appointed for entering the workings, the distress of the neighbourhood was again renewed at an early hour. A great concourse of people collected—some out of curiosity, to witness the commencement of an undertaking full of sadness and danger—some to stir up the revenge and aggravate the sorrows of the relatives of the sufferers, by calumnies and reproaches, published for the sole purpose of mischief; but the greater part came with broken hearts and streaming eyes, in expectation of seeing a father, a husband, or son, "brought up out of the horrible pit!"

As the weather was warm, and it was desirable that as much air might pass down the shaft as possible, constables were placed at proper distances, to keep off the crowd. Two surgeons were also in attendance in case of accidents.

At six o'clock in the morning, Mr. Straker, Mr. Anderson, the overman of the colliery, and six other persons, descended the William pit, and began to traverse the north drift towards the plane board. As a current of water had been constantly diverted down this shaft for the space of ten hours, the air was found to be perfectly cool and wholesome. Light was procured from steel-mills. As the explosion had occasioned several falls of large masses of stone from the roof, their progress was considerably delayed by removing them. After the plane-board was reached, a stopping was put across it on the right hand, and one across the wall opposite the drift. The air, therefore, passed to the left, and number six was found.

The shifts of men employed in this doleful and unwholesome work were generally about eight in number. They were four hours in and

eight hours out of the mine: each individual, therefore, wrought two shifts every 24 hours.

When the body of number six was to be lifted into a shell or coffin, the men for a while stood over it in speechless horror: they imagined it was in so putrid a state, that it would fall asunder by lifting. At length they began to encourage each other "in the name of God" to begin; and after several hesitations and resolutions, and covering their hands with oakum to avoid any unpleasant sensation from touching the body, they laid it in a coffin, which was conveyed to the shaft in a bier made for the purpose, and drawn 'to bank' in a net made of strong cords.

When the first shift of men came up, at ten o'clock, a message was sent for a number of coffins to be in readiness at the pit. These being at the joiner's shop, piled up in a heap to the number of 92, (a most gloomy sight) had to pass by the village of Low Felling. As soon as a cart-load of them was seen, the howlings of the women, who had hitherto continued in their houses, but now began to assemble about their doors, came on the breeze in slow fitful gusts, which presaged a scene of much distress and confusion being soon exhibited near the pit; but happily, by representing to them the shocking appearance of the body that had been found, and the ill effects upon their own bodies and minds, likely to ensue from suffering themselves to be hurried away by such violent convulsions of grief, they either returned to their houses, or continued in silence in the neighbourhood of the pit.

From the 8th of July to the 19th of September, the heart-rending scene of mothers and widows examining the putrid bodies of their sons and husbands, for marks by which to indentify them, was almost daily renewed; but very few of them were known by any personal mark—they were too much mangled and scorched to retain any of their features. Their clothes, tobacco-boxes, shoes, and the like, were, therefore, the only indexes by which they could be recognised.

At the crane twenty-one bodies lay in ghastly confusion: some like mummies, scorched as dry as if they had been baked. One wanted its head, another an arm. The scene was truly frightful. The power of the fire was visible upon them all; but its effects were extremely various: while some were almost torn to pieces, there were others who appeared as if they had sunk down overpowered with sleep.

The ventilation concluded on Saturday the 19th of September, when the 91st body was dug from under a heap of stones. At six o'clock in the morning the pit was visited by candle light, which had not been used in it for the space of 117 days; and at eleven o'clock in the morning the tube-furnace was lighted. From this time the colliery has been regularly at work; but the 92d body has never yet been found.

All these persons (except four, who were buried in single graves) were interred in Heworth Chapel-yard, in a trench, side by side, two coffin deep, with a partition of brick and lime between every four coffins.

A dreadful and destructive explosion of carbureted hydrogen gas took place in the Success coal-pit, near Newbottle, belonging to Nesham and Co. in the county of Durham, at half past four o'clock, on June the 2d, 1815. By this unfortunate accident, which had repeatedly occurred at the same pit, 57 persons were killed upon the spot, and several wounded.

The immediate cause of the catastrophe was not clearly ascertained, though it was generally believed that the pitmen had inadvertently worked into the old workings, or some place where there had been a large collection of inflammable air.

As all the unfortunate labourers were instantly killed, and as the rapid return of atmospheric air after the explosion destroyed the headings and air courses, the whole of the colliery became so completely altered, that no correct idea of the cause of the accident could be formed from appearances. It appeared also, that from some unaccountable circumstance, that the atmospheric air could not be sent down in sufficient quantity, and in a proper direction after the explosion, to those persons who might have lived till their scanty supply of atmospheric air became exhausted.

When the explosion took place, 72 men and boys were at work at the depth of 108 fathoms; and though the greatest endeavours were made to relieve those distressed persons, only 15 survived, some of whom were in a very precarious state. The explosion was so great as to carry every thing before it, till it was impeded in its progress by a large waggon, which, with the driver and horse, were dashed to pieces.

Several men in the colliery, after they had escaped this tornado of fire, endeavoured to reach the shaft; but death arrested them on their road; for breathing an atmosphere surcharged with carbonic acid gas, their destruction now became inevitable.

Some of the men survived till they were brought up the shaft into the atmosphere, when they died, perhaps unable to bear the stimulus of the atmospheric air after the state of exhaustion in which they had previously lived for some time.

After a considerable explosion takes place in a coal-mine, the pitmen are often drenched with water, which is probably occasioned by the rapid combustion of hydrogen gas in such a confined situation, as may be readily understood by persons conversant with chemistry. At the same time all the partitions and divisions being broken down, whilst the air-courses are converted into a complete wreck, and the whole atmosphere of the mine so much agitated, it is to be expected that the carbonic acid gas will be distributed through the bottom of the mine, and suffocation become the fate of those persons who escape the immediate effects of the explosion. Out of 19 horses only six died.

The occurrence of this, and similar accidents, was rendered still more afflicting by misfortunes of a different nature, which, though not connected with the fire damp, are deserving of record. At another pit belonging to the very same proprietors, Nesham and Co. and on the same scite, a melancholy accident occurred within less than a month after the explosion. The proprietors had provided a powerful locomotive steam engine for the purpose of drawing 10 or 12 coal waggons to the staith at one time; and Monday, July 2d, 1814, being the day it was to be put in motion, a great number of persons belonging to the colliery had collected to see it. Unfortunately just as it was going off, the boiler of the machine burst. The engine man was dashed to pieces, and his mangled remains blown 114 yards: the top of the boiler (nine feet square, in weight 19 cwt.) was blown 100 yards; and the two cylinders 90 yards. At the fatal blast which had recently taken place, the first who arrived at the bank, holding by a rope, was a little boy about seven years of age. This poor little fellow was thrown upon this

occasion to a considerable distance and killed. The accident was occasioned by the folly of the engine man, who said that as there were several owners and viewers there, he would make her (the engine) go off in grand style, and he had got upon the boiler to loose the screw of the safety valve, which being over-heated, unfortunately exploded. Fifty-seven were killed and wounded, and of the latter but few recovered.

Nor were Messrs. Nesham and Co. the only sufferers. Two months before the occurrence of the last accident, another equally dreadful had occurred at Heaton Main colliery, near Newcastle. This colliery is situated in the bed of coal called the high main. It is a considerable depth, about 110 fathoms, and the shaft is situated at the lower extremity of the mine. The shaft is divided by boarding all the way down, so that the same opening served for the up and down cast shaft. The seam towards the rise had been formerly worked as a colliery, under the name of Heaton Banks, by shafts distinct from the present working, which shafts, when the colliery was given up, were covered over with boards and earth. In the course of time these old workings had become filled with water; and the managers of the present colliery being well aware of the danger attending so large an accumulation of water, the workings were proceeded in with the utmost caution.

The mine was very much subject to what the colliers call the creep, which is a gradual filling up of the horizontal passages. It had been customary for some time past to bore in various directions upon the lines the men were working, in order to ascertain whether any body of water lay concealed in the adjacent cavities. This precaution was about to be put in practice at nine o'clock on Wednesday the 3d of May; but before that time had arrived (between three and four o'clock in the morning), a dreadful rush of water came through the roof in the north-west part of the colliery, and continued to flow with such rapidity, that only 20 men and boys were enabled to make their escape. In a very short time, the water closed up the lower mouth of the shaft; and that night it rose to the height of 24 fathoms. Some faint hopes being entertained that the men below would retire to the higher parts of the workings, which were said to be above the level of the water in the shaft, every exertion was used to open a communication with them by the old workings. Considerable difficulties, however, presented themselves: The rubbish which covered and choaked up the two old shafts, when deprived of the support of the water, fell in dragging along with it some trees which had been planted round the spot. An old shaft in the front of the Heaton hole, did not however present a like impediment, and consequently every exertion was used to open a communication by that way. They had uncovered the pit, and reached the scaffolding (on Saturday the 6th of May), which was five fathoms from the surface, and were partly successful. After the accident three large engines (one of 130 horse power) were constantly employed in drawing the water from the pit, at the rate of 1200 galloons per minute, yet two days after the accident, it was found to have attained the height of 31 fathoms, but it afterwards decreased, and expectations were entertained of the colliery being at some future period set to work—we hope under better regulations. Mr. Miller, the under-viewer (who left a wife and eight children), 32 workmen, 42 boys, and 37 horses perished; and 25 widows, with about 80 children, were left to bemoan the sudden

death of their husbands and fathers. It thus appears, that in the short space of two months, 189 persons were numbered with the dead at the Heaton and Success collieries. The indignation of many individuals was extreme at the negligence displayed in permitting the steam-engine to be over-fired, and suffering the water to gain so decided an ascendancy. These were dangers which caution might have averted, but the explosion occasioned by inflammable air, no human sagacity at that period could have prevented. The proprietors of the mines had the good sense to perceive, that accidents from water and the steam-engine depend in some measure on the discretion of their servants, but that the prevention of explosion by the fire damp must be determined by some regular mode of lighting, dependant on a general principle. In the agitation of the moment, but not without reflection, they applied to Sir Humphrey Davy, who immediately complied with their solicitations, and proceeded to the spot. The result of his enquiries will be best communicated in his own simple, and energetic language.

After ascertaining, by a variety of experiments, the combustibility and explosive nature of the fire-damp in mines, and finding that a mixture of this gas with air would not explode in metallic canals or troughs, when their diameter was less than one-seventh of an inch, and that explosions would not pass through such canals: also that explosions would not pass through very fine wire sieves or wire gauze, Sir Humphrey Davy comes to the following inference:

"It is evident, that to prevent explosions in coal mines, it is only necessary to use air-tight lanterns, supplied with air from tubes or canals of small diameter, or from apertures covered with wire gauze placed below the flame, through which explosions cannot be communicated, and having a chimney at the upper part on a similar system, for carrying off the foul air. Common lanterns may easily be adapted to the purpose by being made air-tight in the door and sides, by being furnished with the chimney, and with the system of safety apertures below and above.

"The principle being known, it was easy to adopt and multiply practical applications of it. The first safe lantern that I had constructed was made of tin-plate, and the light emitted through four glass plates in the sides. The air was admitted round the bottom of the flame, from a number of metallic tubes, of one-eighth of an inch in diameter, and one inch and a half long. The chimney was composed of two open cones, having a common base perforated by two small apertures, and fastened to the top of the lantern, which was made tight in a pneumatic rim containing a little oil. The upper and lower apertures in the chimney were about one-third of an inch, the lamp, which was fed with oil, gave a steady flame about an inch high, and half an inch in diameter. When the lantern was slowly moved, the lamp continued to burn, but more feebly; and when it was rapidly moved it went out. To obviate this circumstance, I surrounded the bottom of the lantern with a perforated rim, and this arrangement perfectly answered the end proposed.

"I had another chimney fitted to this lantern, furnished with a number of safety tin-plate tubes of one-sixth of an inch in diameter, and two inches long; but they diminished considerably the size of the flame, and rendered it more liable to go out by motion; and many experiments appear to shew that if the diameter of the upper orifice of the chimney be not very

large, it is scarcely possible, that any explosion produced by the flame can reach it.

"I gradually threw an explosive mixture of fire-damp and air into the safe-lantern from a bladder furnished with a tube which opened by a large aperture above the flame. The flame became enlarged, and by a rapid jet of gas, I produced an explosion in the body of the lantern. There was not even a current of air through the safety tubes at the moment, the flame did not appear to reach above the lower aperture of the chimney, and the explosion merely threw out from it a gust of foul air.

"It is evident therefore, that when in the safe-lantern, the air gradually becomes contaminated with fire-damp, this fire-damp will be consumed in the body of the lantern, and that the air passing through the chimney cannot contain any inflammable mixture.

"As the wick may be moved without communication between the air in safe-lanterns or lamps and the atmosphere, there is no danger in trimming or feeding them; but they should be lighted in a part of the mine where there is no fire-damp, and by a person charged with the care of the lights. By these inventions, used with such simple precautions, there is reason to believe that a number of lives will be saved, and much misery prevented. Where candles are employed in the open air, in the mines, life is extinguished by the explosion; with the safe-lantern, or safe-lamp, the light is only put out, and no other inconvenience will occur."

Ingenious as many of these discoveries were regarded at the period when they were first announced, they have been surpassed, and almost superseded, by a subsequent discovery. Sir Humphrey conceived it possible the impurity and density of the fire-damp might prevent it from entering apertures extremely small, though sufficiently large to admit the diffusion of light. His conjecture was justified by experiments, and the wire-gauze lamps were introduced into the coal mines under his direction. The wire-gauze covers the top of a common lamp, communicates a steady light, and is not susceptible of explosion. The texture of the wire-gauze is sometimes so extremely fine, that a single inch is perforated by 288 apertures. So simple and efficacious a mode of preserving human life demands the admiration and the gratitude of mankind

Preservation of Persons apparently Drowned.

The opinions of physicians on the subject of drowning have been various and contradictory. Dr. Cullen says, that very often the water does not enter the lungs, nor even the stomach in any material quantity, and that, in most cases, no injury is done to the organization of the vital parts. Hence he argues, that the death which seems to ensue is owing to the stoppage of respiration, and the consequent ceasing of the circulation of the blood; by which the body loses its heat and vital principle.

Mr. Hunter advances the following theory: The loss of motion in drowning seems to arise from the loss of respiration, and the immediate effect this has on the other vital motions of the animal; at least this privation of breathing appears to be the first cause of the heart's motion ceasing. It is most probable, therefore (observes Mr. Hunter), that the restoration of breathing is all that is necessary to restore the heart's motion, for if a sufficiency of life still remain to produce that effect, we may suppose every part equally ready to move at that very instant when the

action of the heart takes place, their actions depending so much upon it. This is rendered probable by the circumstance that children in the birth, when too much time has been spent after the loss of that life which is peculiar to the fœtus, lose altogether the disposition for the new life: in such cases there is a total suspension of the functions of vitality; the child remains to all appearance dead, and would die if air were not thrown into its lungs, and the first principle of action by that means restored. To put this in a clearer light, Mr. Hunter gives the result of some cruel and by no means justifiable experiments. A pair of double bellows were provided, which were so constructed, that by one action air was thrown into the lungs, and by the other, air was sucked out, which had been thrown in by the former, without mixing together. The muzzle of these bellows was fixed into the trachea of a dog, and by working them he was kept perfectly alive. While this artificial breathing was going on, the stermune was taken off, so that the heart and lungs were exposed to view. The heart then continued to act as before, only the frequency of its acting was greatly increased. Mr. Hunter then stopped the motion of the bellows, and observed that the contraction of the heart became gradually weaker and less frequent, till it left off moving altogether; but by renewing the operation, the motion of the heart also revived, and soon became as strong and frequent as before. This process was repeated on the same dog ten times, sometimes stopping for 9 or 10 minutes. Mr. Hunter observed that every time he left off working the bellows, the heart became extremely turgid with blood, and the blood in the left side became as dark as that in the right, which was not the case when the bellows were working. These situations of the animal seemed to be exactly similar to drowning.

Dr. Goodwyn has since endeavoured to ascertain the effects of submersion on living animals in a still more accurate manner, and deduces from his experiments the following conclusions: 1. A small quantity of fluid usually passes into the lungs in drowning. 2. This water enters the lungs during the efforts to inspire, and mixing with the pulmonary muscles, occasions the frothy appearance so observable. 3. The whole of this fluid in the lungs is not sufficient to produce the changes that take place in drowning. Hence the doctor concludes, that the water produces all the changes that take place in drowning, indirectly, by excluding the atmospheric air as its purest part. For this reason he recommends inflating the lungs with that kind of air in preference to any other.

From those opposing views of the question, physicians have seldom agreed respecting the methods of recovery; and all reference to theory is fortunately rendered unnecessary by the plain and practical instructions of the Humane Society, which are founded on the simplest principles, and are sanctioned by experience.

The founder of the Humane Society was the amiable and accomplished Dr. Hawes. It is no less a debt due to the Society than a duty which we owe to him, to state, in this place, the very important services he rendered his country, and the great obligations he conferred on the human race, by his benevolent and arduous exertions in establishing this institution; by his unwearied assiduity in conducting it, through much opprobrium and opposition, to its present state of prosperity; and by his unremitting perseverance in extending its humane and beneficent views to numerous cities and towns of the United King-

dom, to various parts of Europe, to the East and West Indies, and to America.

About the middle of the last century, Dr. John Fothergill saw the dubiousness and fallacy of the received criteria of dissolution; and, in a paper addressed to the Royal Society, maintained "the possibility of saving many lives, without risking any thing." Though coming from such high authority, the subject attracted no attention; and notwithstanding the great interest with which, *a priori*, it was natural to suppose it would fill every thinking mind, we hear no more of it, at that time, among our own countrymen.

Though several instances had occurred, in various parts of the continent, which pointed out the possibility of recovering, in many cases, those who were drowned; yet the attention they excited was limited and transient.

M. Reamur communicated, in 1767, to the Academy of Sciences at Paris, some instances of resuscitation which had occurred in Switzerland.

Holland, being intersected by numerous canals and inland seas, its inhabitants were, consequently, much exposed to accidents by water; and many persons were drowned from the want of proper assistance. Hence, in the year 1767, a society was formed at Amsterdam, which offered premiums to those who saved the life of a citizen in danger of perishing by water: it proposed to publish the methods of treatment, and to give an account of the cases of recovery. Instigated by this example, the magistrates of health at Milan and Venice, issued orders, in 1768, for the treatment of drowned persons. The city of Hamburgh appointed a similar ordinance to be read in all the churches, extending their succour, not merely to the drowned, but to the strangled, to those suffocated by noxious vapours, and to the frozen. The first part of the Dutch memoirs was translated into the Russian language, by command of the Empress. In 1769 an edict was published in Germany, extending its directions and encouragements to every case of apparent death, which afforded a possibility of relief. In 1771, the magistrates of the city of Paris founded an institution in favour of the drowned, &c. And the repeated instances of success in each country abundantly confirmed the truth of the facts related in the Amsterdam memoirs. These memoirs were, in 1773, translated into English by Dr. Cogan, in order to convince the British public of the practicability, in many instances, of recovering persons who were apparently dead, from drowning. No sooner were they translated than they engaged the humane and benevolent mind of Dr. Hawes. His very soul was absorbed with the animating hope of saving the lives of his fellow-creatures: but, in making the attempt, he had to encounter both with ridicule and opposition. The practicability of resuscitation was denied. He ascertained its practicability, by advertising to reward persons, who, between Westminster and London bridges, should, within a certain time after the accident, rescue drowned persons from the water, and bring them ashore to places appointed for their reception, where means might be used for their recovery, and give immediate notice to him. Many lives were thus saved by himself and other medical men, which would otherwise have been lost. For twelve months he paid the rewards in these cases; which amounted to a considerable sum. Dr. Cogan remonstrated with him on the injury which his private fortune would sustain from a per-

severance in these expences; he therefore consented to share them with the public. They accordingly agreed to unite their strength, and each of them to bring fifteen friends to a meeting at the Chapter Coffee-house, with the express intention of establishing a Humane Society in London: this was happily accomplished in the summer of 1774. The object of this society was then, like that at Amsterdam, confined to the recovery of persons who were apparently dead from drowning.

The names of these thirty gentlemen, who, with Dr. Hawes and Dr. Cogan, laid the foundation of the society, deserve to be recorded. The following is a list of them.

Mr. Armiger
Rev. Mr. Bouillier
Frederick Bull, Esq. and Alderman
Dr. William Cooper
Mr. Delver
Mr. Denham
Mr. William Fox
Dr. Goldsmith
Rev. Richard Harrison
Mr. Benjamin Hawes
Dr. Heberden
James Horsfall, Esq. F. R. S.
Mr. John Jacob
Mr. Joseph Jacob
Rev. Dr. Jeffries
Dr. Kooystra
Robert Palmer, Esq.
Mr. Patten
Mr. Michael Pearson
Mr. Phipps
Samuel Prime, Esq.
Mr. John Bewley, Rich
Rev. Mr. Sowden
Thomas Tower, Esq.
Rev. Dr. Towers
William Towgood, Esq.
Mr. William Townsend
Rev. Mr. Van Effen
Mr. Warrand
Dr. Watkinson
Mr. Wright

Those who remember the first establishment of this society recollect what extreme caution was then requisite in receiving the accounts of persons said to have been drowned and subsequently recovered. Both Dr. Hawes and Dr. Cogan saw the absolute necessity of guarding against the attempts which might be made, and were made, to impose on them in these respects. The very existence of the society, and the proof that resuscitation was possible, depended on the facts being duly authenticated. Dr. Hawes, therefore, was no less indefatigable than his able colleague, in ascertaining the accuracy of the statements of recovery which were sent to them, as well as the justness of the claims which were made for rewards. And it is scarcely possible for any, but those who witnessed them, to conceive of the great labour and constant fatigue which were thus rendered necessary, during the infancy of the institution. Yet Dr. Hawes, notwithstanding his unremitting attention to the duties of an extensive practice, persevered in the closest investigation of every case, that he might be enabled satisfactorily to refute the falsehoods which were industriously circulated against him and the society, to expose the calumnies with which they were continually assailed, and to convice the impartial public of the certainty of resuscitation in many cases of drowning. To do this, in the face of such difficulties, required a courage and an ardour of no common kind. But the cause was good: it was the cause of humanity: the heart engaged in the pursuit was the heart of a man whose greatest pleasure and highest gratification were to be instrumental in preserving the lives of his fel-

low-creatures, and whom neither obstacles nor ridicule could intimidate.

For the first six years Dr. Cogan prepared the reports of the society from year to year, nor was Dr. Hawes less attentive in aiding the designs and promoting the views of this institution. Accordingly, we find him in the autumn of 1776, engaged in the arduous task of giving a course of lectures on suspended animation: a subject wholly new and unexplored. The Doctor hoped, by delivering these leetures, to excite an investigation of the subject in all its branches, and to its fullest extent and remotest consequences. But particularly was it his wish to instruct the younger part of the faculty to preserve human life in every critical circumstance in which the vital powers are liable to be suspended; and to lead them into the consideration of the various derangements which interrupt the action of the brain, the heart, or the lungs; and to point out to them the means to be employed in restoring their respective functions. The Doctor fully explained to his pupils the most proper methods to be pursued in recovering persons from syncope, inebriation, trance, drowning, suffocation by the cord or noxious vapours, intense cold, or lightning. He also minutely characterised the several symptoms of apparent death, which sometimes supervene in acute diseases, but which might be often surmounted by suitable measures, speedily adopted and vigorously pursued. The usual signs of death were severally considered by him, and those which are certain distinguished from those which are equivocal. The Doctor continued lectures for many years; and they answered the very important purpose of turning the attention of his hearers to this benevolent, novel, and interesting subject. Still anxious, however, to attract the attention of the faculty to it, and to promote the great object of this society, he offered prize medals for the best dissertations on various subjects more immediately connected with it; and they produced several valuable ones. He proposed, in 1786 and some subsequent years, that our Society should also offer prize medals for the best dissertations on subjects which had a direct reference to suspended animation: they had their desired effect; as we find the Doctor afterwards stating, that "these investigations have essentially contributed to elucidate the theory and improve the practice of resuscitation." Dr. Hawes was actuated by the same beneficent wish in his several publications: his sole view in them was to preserve life, by every means in his power; for his mind was uniformly and ardently employed in the cause of humanity. It was this all-powerful principle which induced him, in 1777, at a considerable expence, to distribute seven thousand copies of his "Address on premature Death and premature Interment;" and to offer "the reward of one guinea to any nurse, or other attendant, on any child or grown person returning to life, by their humane attention; provided the fact was ascertained by a gentleman of the faculty, or three creditable persons."

In the year 1778, a more active part in the management of the affairs of this society devolved on him, by his being chosen its register. This was still increased in the year 1780, when Dr. Cogan returned to Holland. On this event Dr. Hawes greatly regretted the loss of so able a colleague, and lamented that the task of arranging and preparing the annual reports of the society should have "fallen into hands of such inferior ability; but hopes that his zeal will compensate for the want of ability, that the important cause then entrusted to his sole care,

might not be permitted to languish." Those only, who have witnessed the labour and fatigue which the various and multiplied concerns of the society necessarily impose on him who is entrusted with the intire direction of them, can justly appreciate the value and extent of his unceasing exertions for promoting a cause so near his heart, and with which his own happiness, as well as the happiness of others, was interwoven. The Doctor remarks, in the Transactions of the society, that, soon after this time, the execution of the reports of this institution became more complex and intricate. As the instances of resuscitation multiplied, he observes, that new and improved modes of treatment suggested themselves to skilful practitioners; and that other species of apparent death than those hitherto treated were also brought within the reach of art. These circumstances arising from the liberal spirit and unexampled fervour manifested by the medical assistants, in the prosecution of their life-saving views, concurred to render the task more operose and complicated. But, he adds, all these difficulties sunk before the pleasing contemplation of the immense good that would result from it to mankind.

In the year 1796, Dr. Lettsom, who had succeeded Mr. Horsfall as treasurer of the society, resigned; and Dr. Hawes was chosen his successor. He needed not the stimulus of being elected to fill this honourable office of the society to increase his exertions in advancing its interests, or to animate his ardour in promoting its views. He had previously discharged that laborious part of the treasurer's office, which consists in examining into the claims for rewards, and paying them. He had, consequently, to continue these exertions in addition to the other duties attached to this office. Indeed, a man of less ardour, or zeal, or activity, must have failed in raising our society to that degree of eminence which it now possesses. The tide of prejudice, for many years, ran very strong against a set of men, who presumed, or pretended, to bring the dead to life. "Our first object and chief difficulty," the Doctor remarks, "were to remove that destructive incredulity which prevailed. Our attempts were treated, not only by the vulgar, but by some of the learned, even by men of eminence as physicians and philosophers, as idle and visionary, and placed upon a level with professing to raise the dead. The well-authenticated narratives from abroad were considered as fabulous; or, at least, as greatly exaggerated. Such prejudices were first to be removed; and they could only be removed by incontestible facts of our own. Happily, the animated exertions and early subscriptions of a few individuals enabled us to produce them before our little fund was exhausted."

There was another obstacle to the rapid success of the society. In other institutions the subscribers have the means of affording relief to some sick or distressed neighbour; they have a something at their own disposal; some good they can personally confer, when an application is made to them for that purpose. This has nothing of the kind; it has only an anniversary sermon to present to you, and an annual report. But, let it not be forgotten that its patrons and promoters have the god-like satisfaction of knowing they contribute towards preserving the lives of many of their fellow-creatures from premature death. They have, too, a gratification of a most rational and very superior kind, afforded them at these anniversary festivals: they see men, women, and children, walk in solemn procession, and expressing, as they pass, their

fervent gratitude to God and to their benefactors: these have been rescued from an untimely grave; and many, by supporting this institution, have contributed, humanely contributed, to the preservation of their lives aud their restoration to their relatives and friends. This is one of the most interesting and affecting scenes a man of feeling can witness: it seldom fails to cause the tear of kindness and sympathy to steal down the cheek of the spectator.

Under the difficulties which have been mentioned, therefore, it most certainly required all the energy, the patient forbearance, and the unremitting perseverance of Dr. Hawes, to place this institution in that state of respectability and permanence in which he has left it; and to which such a cause is justly entitled. The Doctor asserts (and who will not believe him?) that "he always felt happy in announcing to the public, from year to year, that the glorious cause, for the extension of which this society was established, was advancing in public favour and increasing success." He could "not repress the sensations of almost parental pleasure, which he felt in the survey of the rising state and rapidly increasing importance of an institution, the establishment and promotion of which had employed the best part of his life." He declares too, that "all his labours were amply rewarded, in beholding this institution arrived at a maturity which promises to resist the fate of the varying fashions, that rise and sink in the stream of time." He assures us that "he was abundantly consoled, and even remunerated for all his cares, all his anxieties, and all his solicitudes, when he considered and reflected on the stability which this society has acquired in the conviction of the public mind." And he was persuaded that it will be enabled "to diffuse its blessings to the human race, when Providence shall permit him no longer to be the agent in administering these blessings to his fellow-creatures, or the feeble organ of recording these noblest offices of humanity, for the information and instruction of unborn ages." This period is too soon arrived: we have to lament, though we may acquiesce in, that dispensation of Divine Providence which has deprived the society of his invaluable services. He will long live in its grateful remembrance, and in the grateful remembrance of his country and mankind. He not only proposed the establishment of this truly humane institution, but he fostered it from its birth: he protected it with all the attention, solicitude, and interest of a parent, through the critical periods of infancy and youth: and he reared it, by a prudent and discriminating vigilance for its welfare and utility, to its present vigorous state of manhood.

Dr. Towers, in addressing the general court of directors of the society, in 1776, relative to Dr. Hawes, amongst other things, thus speaks of him: "To the well-known humanity of his disposition, and to that activity of benevolence for which he was so remarkable, this society, in a great degree, owed its origin. The reasonableness and utility of an institution of this kind had been very early seen by him, and therefore he had laboured to promote it, with a diligence and an ardour that will ever do him honour. Indeed, before the establishment of this society, he had publicly advertised rewards for notice to be brought him of any persons in such situations, within a reasonable distance from his own habitation, as those who are now the objects of this institution; which was the strongest demonstration of his solicitude to promote so benevolent a design; and that afterwards, by joining with his worthy col-

league, Dr. Cogan, in adopting the necessary measures for establishing the present institution, he had performed a real service to his country."

The Royal Humane Society will be a standing monument of what may be accomplished by individual persevering exertions in the cause of humanity; and will transmit the name of Hawes to posterity as a benefactor to the human race. He has left us full of years, honour, and usefulness. He is gone to inherit the reward of a life most disinterestedly and assiduously devoted to the preservation of the lives of his fellow-creatures. While we admire and applaud the benevolent zeal, activity, and energy, which he uniformly displayed in his public character, while we love him for his numerous private virtues, let us imitate his example, that we may be associated with him, in the more active, useful, and beneficent pursuits of a future life.

Inscription placed on a Monumental Tablet in Islington Church.

"To perpetuate,
while this frail Marble shall endure,
the meritorious Exertions of an Individual,
and to excite the Emulation of others,
The Governors of the Royal Humane Society
have caused this Tablet to be inscribed
with the Name of WILLIAM HAWES, M. D.;
by whose personal and indefatigable Labours
an Institution honourable to the Nation,
and highly beneficial to the World at large,
was founded, fostered, and matured.
And long, very long, may it flourish,
The Ornament and the Pride of Britain.

This excellent, unassuming, persevering Philanthropist,
was born in Islington, Nov. 28, 1736;
died in Spital Square, Dec. 5, 1808,
and was buried on the 13th, near these Walls.

Go, Reader; and imitate those virtuous Actions,
which the latest Posterity will applaud and venerate,
and which the recording Angel has registered in Heaven.

Well done, good and faithful Servant!
Enter thou into the joy of thy Lord!

[*At Bottom*, The Figure from the Society's Medal;
and the Motto, Lateat Scintillula forsan.]

Subsequent Institutions of other Humane Societies

We have great satisfaction in recording the establishment of similar Humane Societies in various parts of the world; and that the success attending these has exceeded the sanguine expectations of their founders and supporters, viz.

1. *British United Empire.*—Birmingham, Bristol, Exeter, Gloucester, Kingston upon Hull, Lancaster, Northampton, Melton Mowbray, Newcastle upon Tyne, Norwich, Shropshire, Whitehaven, Wisbeach, Bath, Leicester, Eastern coast, York, Rivers, Wreak and Eye, Falmouth,

Suffolk, Bedford.—Aberdeen, Glasgow, Leith, Montrose, Forth and Clyde Navigation.—North Wales, Swansea.—Dublin, Cork.

2. *British Foreign Settlements.*—Madras, Calcutta, Halifax, Nova Scotia, Jamaica.

3. *Foreign.*—Berlin, Gorlitz, Prague, Copenhagen, St. Petersburgh, Algiers, Pennsylvania, Boston, New York, Baltimore.

Directions for the recovery of Drowned Persons, and prevention of premature death.

These objects had engaged the attention of the Society from its commencement, as essentially requisite to effect the purpose for which it was instituted. From this society many others have emanated, and in general adopted the directions of the parent institution; and where they have amplified, they have not weakened the principles, which were founded upon science and confirmed by experience. At the same time, we have availed ourselves of some excellent observations from some of these humane societies, and particularly of those instituted in America, where the extremes of heat and cold greatly exceed those of the British empire.

1. *Treatment of Drowned Persons.*—In removing the body to a convenient place, care must be taken that it be not bruised, nor shaken violently, nor roughly handled, nor carried over any man's shoulders with the head hanging downwards, nor rolled upon the ground, nor over a barrel, nor lifted up by the heels; for experience proves that all these methods may be injurious, and destroy the small remains of life. The unfortunate object should be cautiously conveyed by two or more persons; or in a carriage upon straw, lying as on a bed, with the head a little raised, and kept in as natural and easy a position as possible.

The body being well dried with a cloth or flannel, should be placed in a moderate degree of heat, but not too near a large fire. The window or door of the room should be left open, and no more persons be admitted into it than those who are absolutely necessary; as the lives of the patients greatly depend upon their having the benefit of pure air. The warmth most promising of success is that of a bed or blanket well heated. Bottles of hot water should be laid at the bottoms of the feet, to the joints of the knees, and under the arm pits; and a warming pan moderately heated, or hot bricks wrapped in cloths, should be passed over the body. The natural and kindly warmth of a healthy person lying by the side of the body has been found in some cases, particularly of children, very efficacious.

Should the accident happen in the neighbourhood of a warm bath, brewhouse, bakehouse, glasshouse, or any fabric where warm lees, ashes, embers, grains, sand, water, &c. are easily procured, it would be of great importance to place the body in any of these, moderated to a degree of heat little exceeding that of a healthy person; or in summer, the exposure to sunshine has been proved obviously beneficial. Friction with the hand, or with warm flannel or coarse cloth, so as not to injure the skin, should also be tried with perseverance for a considerable period of time.

The subject being placed in one or other of these advantageous circumstances as speedily as possible; a bellows should be applied to one nostril, whilst the other nostril and the mouth are kept closed, and the lower end of the prominent part of the wind-pipe is pressed backward.

The bellows is to be worked in this situation; and when the breast is swelled by it, the bellows should stop, and an assistant should press the belly upwards to force the air out. The bellows should then be applied as before, and the belly again to be pressed; this process should be repeated from twenty to thirty times in a minute, so as to imitate natural breathing as nearly as possible. Some volatile spirits heated may be held under the valve of the bellows whilst it works. If a bellows cannot be procured, some persons should blow into one of the nostrils, whilst the mouth and the other nostril are closed as before.

If there be any signs of returning life, such as sighing, gasping, twitching, or any convulsive motions, beating of the heart, the return of the natural colour and warmth; opening a vein in the arm, or external jugular of the neck, may prove beneficial, but the quantity of blood taken away should not be large. The throat should be tickled with a feather, in order to excite a propensity to vomit, and the nostrils also with a feather, snuff, or any other stimulant, so as to provoke sneezing. A tea spoonful of warm water may be administered now and then, in order to learn whether the power of swallowing be returned; and if it be, a table spoonful of warm wine or brandy and water, may be given with advantage; and not before, as the liquor might fall into the lungs before the power of swallowing returns. The other methods should be continued with ardour and perseverance for two hours or upwards, although there should not be the least symptom of life.

In the application of stimulants, electricity has been recommended, and when it can be early procured, its exciting effects might be tried in aid of the means already recommended; but the electrical strokes should be given in a low degree, and gradually as well as cautiously increased.

Other objects of the Humane Society.

Suspension by the Cord or Hanging.—In hanging, the external veins of the neck are compressed by the cord, and the return of the blood from the head thereby impeded, from the moment that suspension takes place; but, as the heart continues to act for a few seconds after the windpipe is closed, the blood which is sent to the head during this interval is necessarily accumulated there. Hence it is, that in hanged persons (strangulation) the face is greatly swollen, and of a dark red or purple colour; the eyes are commonly suffused with blood, enlarged, and prominent.

From the great accumulation of blood in the vessels of the head, many have been of opinion that hanging kills chiefly by inducing apoplexy; but it has, however, been clearly proved, that in hanging, as well as in drowning, the exclusion of air from the lungs is the immediate cause of death. From which it appears, that the same measures recommended for drowned persons are also necessary here; with this addition, that opening the jugular vein, or applying cupping-glasses to the neck, will tend considerably to facilitate the restoration of life, by lessening the quantity of blood contained in the vessels of the head, and thereby taking off the pressure from the brain.—Except in persons who are very full of blood, the quantity taken away need seldom exceed an ordinary tea-cupful, which will, in general, be sufficient to unload the vessels of the head, without weakening the powers of life.

To prevent the effects of Lightning.—When persons happen to be over-

taken by a thunder-storm, although they may not be terrified by the lightning, yet they naturally wish for shelter from the rain which usually attends it; and, therefore, if no house be at hand, generally take refuge under the nearest tree they can find. But in doing this, they unknowingly expose themselves to a double danger; first, because their clothes being thus kept dry, their bodies are rendered more liable to injury, the lightning often passing harmless over a body whose surface is wet; and, secondly, because a tree, or any elevated object, instead of warding off, serves to attract and conduct the lightning, which, in its passage to the ground, frequently rends the trunks or branches, and kills any person or animal who happens to be close to it at the time. Instead of seeking protection, then, by retiring under the shelter of a tree, hay-rick, pillar, wall, or hedge, the person, should either pursue his way to the nearest house, or get to a part of the road or field which has no high object that can draw the lightning towards it, and remain there until the storm has subsided.

It is particularly dangerous to stand near leaden spouts, iron gates, or palisadoes, at such times; metals of all kinds having so strong an attraction for lightning, as frequently to draw it out of the course which it would otherwise have taken.

When in the house, avoid sitting or standing near the window, door, or walls, during a thunder gust. The nearer you are placed to the middle of a room, the better.

The greatest danger to be apprehended from lightning is explosion of powder-magazines, which might, in a great degree, be secured from danger by insulation, or by lining the bulk, heads, and floorings, with materials of a non-conducting nature, the expence of which would not be great.

When a person is struck by lightning, strip the body, and throw buckets-full of cold water over it for ten or fifteen minutes; let continued frictions and inflations of the lungs be also practised; let gentle shocks of electricity be made to pass through the chest, when a skilful person can be procured to apply it; and apply blisters to the breast.

Additional Means for the Preservation of the Lives of Seamen.

The moment an alarm is given, that a man is overboard, the ship's helm should be put down, and she should be hove in stays; an object that can float should also be thrown overboard as near the man as possible, with a rope tied to it, and carefully kept sight of, as it will prove a beacon, towards which the boat should pull as soon as lowered down. A grand primary object is, having a boat ready to lower down at a moment's notice, which should be hoisted up at the stern most convenient; the lashings, tackle, &c. to be ever kept clear, and a rudder, tiller, and spare oar, ever to be kept in her; and when dark, she should not be without a lanthorn and a compass.

There should also be kept in her a rope with a running bowline, ready to fix in or to throw to the person in danger; coils of small rope, with running bowlines, should also be kept in the chains, quarters, and abaft, ready to throw over, as it most generally occurs that men pass close to the ship's side, and have been often miraculously saved by clinging to ropes.

Sailors have no conception that mephitic air will be productive of

immediate apparent death. It is granted by most seamen, that smoking or fumigating ships with charcoal is the most effectual means of killing all kinds of vermin, and is therefore always resorted to.

It is recommended, for the certain preservation of our brave defenders, that no sailor nor boy be allowed to go under the decks until the hatches, and all the other openings, have been for three hours uncovered; in that time all noxious vapours will be effectually detached.

To prevent the fatal Effects of drinking Cold Water, or Cold Liquors of any kind, in Warm Weather, or when heated by Exercise, or otherwise.

Avoid drinking whilst warm, or, drink only a small quantity at once, and let it remain a short time in the mouth before swallowing it; or, wash the hands and face, and rince the mouth with cold water before drinking. If these precautions have been neglected, and the disorder incident to drinking cold water hath been produced, the first, and in most instances, the only remedy to be administered, is sixty drops of liquid laudanum in spirit and water, or warm drink of any kind.

If this should fail of giving relief, the same quantity may be given twenty minutes afterwards.

When laudanum cannot be obtained, rum and water, or warm water, should be given. Vomits and bleeding should not be used without consulting a physician.

To prevent the Effects of Excessive Cold.

Persons are in danger of being destroyed by it, when they become very drowsy, or are affected with general numbness or insensibility of the body. As the cold which proves fatal generally affects the feet first, great care should be taken to keep them as warm as possible; by protecting them when exposed to cold with wool, or woollen socks within the shoes or boots, or with large woollen stockings drawn over them, or when riding, with hay or straw wrapped round them; by keeping up a brisk circulation in the blood-vessels of the feet, which will be best preserved by avoiding tight boots or shoes, by moving the feet constantly; or, when this is impracticable, from a confined situation, and two or more persons are exposed together, by placing their feet, without shoes, against each other's breasts.

Where the cold has produced apparent death, the body should be placed in a room without fire, and rubbed steadily with snow, or cloths wet with cold water, at the same time that the bellows is directed to be applied to the nose, and used as in the case of drowning. This treatment should be continued a long time, although no signs of life appear; for some persons have recovered, who appeared lifeless for several hours.

When the limbs only are affected by the cold, they should be rubbed gently with snow, or bathed in cold water, with ice in it, until the feeling and power of motion returns; after which, the bathing, or the rubbing with snow is to be repeated once every hour, and continued a longer or shorter time, as the pains are more or less violent.

To prevent Danger from Exposure to the Excessive Heat of the Sun.

Affections from this cause, or strokes of the Sun, so called, may be suspected, when a person exposed to its rays is seized with a violent head-ach, attended with throbbing or giddiness; followed with faintness

and great insensibility, heat and dryness of the skin, redness and dryness of the eyes, difficulty of breathing; and, according as the disease is more or less violent, with a difficulty, or entire inability of speaking or moving.

To guard against these dangerous effects of heat, it will be proper to avoid labour, or violent exercise, or exposure to the rays of the sun immediately after a hearty meal. To avoid drinking spirits of any kind. Small beer, vinegar and water sweetened with sugar, or any thin cooling beverage, are alone proper for persons exposed to the excessive heat of the sun.

Should the symptoms increase, it will be proper to remove the affected person into a cool place, to open the garments, particularly about the neck and breast, and if the pulse beat forcibly, to bleed immediately, the quantity proportioned to the strength of the pulse; but, should the pulse be weak, bleeding must not be performed.

The feet and legs, and even the lower portion of the body, may be placed in cold water. Should, however, this process prove ineffectual, linen cloths wet with cold water, or water and vinegar, may be applied to the temples, and over the whole head; and draughts of vinegar and water sweetened may be freely drank.

The dangerous Effects of Noxious Vapours, from Wells, Cellars, Fermenting Liquors, &c. may be prevented,

By procuring a free circulation of air, either by ventilators, or opening the doors or windows where it is confined, or by changing the air, by keeping fires in the infected place, or by throwing in stone-lime recently powdered.

When a person is apparently dead from the above-mentioned cause, the first thing to be done is to remove the body to a cool place in a wholesome air; then let the body be stripped, and let cold water be thrown from buckets over it for some time. This is particularly useful in cases of apparent death from drunkenness.—Let the treatment now be the same as that for drowned persons.

Burning of Females, by their Clothes having caught Fire.

A by-stander, or the first person who is present, should instantly pass the hand under all the clothes to the sufferer's shift, and raise the whole together, and closed over the head, by which the flame will indubitably be extinguished, and this may be effected in a few seconds, that is, in the time that a person can stoop to the floor, and rise again; and no other method can be so ready, expeditious, and effectual.

The sufferer will facilitate the business, and also prevent serious injury, by covering her face and bosom with her hands and arms—Should it happen that no person is nigh to assist her, she may in most cases, if she has presence of mind, relieve herself, by throwing her clothes over her head, and rolling or lying upon them.

The females and children in every family should be told, and shewn, *Flame always tends upwards*—and that, consequently, while they remain in an upright posture, with their clothes on fire (it usually breaking out in the lower part of the dress), the flames, meeting additional fuel as they rise, become more powerful and vehement in proportion—whereby the bosom, face, and head, being more exposed than

other parts to this intense heat, or vortex of the flames, must necessarily be most injured; therefore, in such situation, when the sufferer is alone, and incapable, from age, infirmity, or other cause, of extinguishing the flames, by throwing the clothes over her head, as before directed; she may still avoid much torture, and save life, by throwing herself at full length on the floor, and rolling herself thereon—By this method the flames may possibly be extinguished; their progress will infallibly be retarded; the bosom, face, and head, preserved from injury; and an opportunity be afforded for assistance.

The following have been some of the Appearances on Dissection of the Drowned.

The Brain.—In the first place:—The vessels of the brain are of a remarkably dark colour, but not turgid, nor is there usually any extravasated blood.

The Bronchia. 2.—There is found in the upper bronchial cavities a certain frothy fluid, of a palish red.

Lungs. 3.—The lungs are more livid than in their healthy state; and both the veins and arteries are considerably distended, by a large quantity of black blood.

Heart. 4.—The right auricle and ventricle of the heart are filled with blood of a dark colour: in the left auricle and ventricle there is found a considerable quantity of blood of a similar appearance.

Arteries. 5.—In the last place—in examining minutely the trunks and branches of the arteries to their utmost perceptible extent, we find them universally suffused with blood of a very dark colour.

Cases of Recoveries from apparent Death or imminent Danger.

Although it may be observed with concern, that many unhappy objects of intended suicide, particularly of the female sex, have come under the notice of the society, it must afford some alleviation of pain to the feeling mind, to be informed that no instance of a second attempt has occurred; which probably has resulted from the care exercised by the society in conveying to these objects, not only religious counsel, but also presenting them with Bibles and other appropriate books.

In perusing the histories of the numerous recoveries from extreme danger, which have lately occurred, contrasted with the diminution of fatal cases, it may be inferred, that the rewards proposed, and punctually paid, have contributed with the impulses of humanity, in exciting more immediate and prompt exertions to save life. Many instances have been afforded, even of youths having braved every danger, at the hazard of their own lives, to save those of their fellow-creatures. Undoubtedly the improvement in the means of resuscitation has contributed some share in this happy revolution.

The following case of recovery from the effects of suspension by the cord is communicated by Dr. Addington:

The subject of this case was John Horsell, a stout boy of 16 years of age, in the service of Mr. Bredaz, at a tavern in Elder-street, Spitalfields. No assignable reason for his conduct has been discovered.—He was in his usual state of health, and had not shewn any material unhappiness or discontent, nor been guilty of any thing to occasion the displeasure of his master or other persons around him. There is some

reason to believe that he might have been slightly intoxicated, but this was not very apparent to his companions.

The facts of the case are as follows:—On Saturday night, the 3d of September 1808, about 12 o'clock, on going up stairs to bed, with a younger boy, his fellow-servant, he laid hold of a horse-hair clothes-line, which was suspended loosely across the garret where they slept, and jocosely telling his companion he would shew him how people hanged themselves, he coiled it rouud his neck, and with both hands drew it tight, till his face became bloated and discoloured.—On seeing this, the little boy who was with him endeavoured to loosen the cord from his neck; but Horsell, to prevent it, beat him off with his hands, and at the same time, quitting his standing by sliding his feet along the floor, he became violently agitated, and completely suspended.—The other boy now ran down stairs and gave the alarm, when Robert Franklin, a youth of 17, a nephew of Mr. Bredaz, hastened to the room, and with his knife, which with great presence of mind he had taken from his pocket and opened as he ran up the stairs, cut the line, and released the miserable sufferer from his suspension. His face was now black and swollen, and he fell completely senseless on the floor. Four gentlemen, viz. Mr. Stratton, Mr. Ferry, Mr. Bowley, and Mr. Gibbs, who were in the house, immediately went up stairs to give assistance, and Mr. Bredaz, at the same instant, sent out for medical aid. By the time I reached the chamber it is supposed that from fifteen to twenty minutes had elapsed from the moment of strangulation.

I found the patient under the care of the four gentlemen above-named, who were rubbing the extremities, stimulating his nostrils with the smoke of tobacco, and using such methods as occurred to them of supporting the remains of life; and it is but justice to them to mention that they staid on the spot throughout the night, and by their humane and active assistance, contributed greatly to the efficiency of the measures which were employed. The master of the boy also, Mr. Bredaz, and his whole family, rendered every possible aid and exertion with the most diligent and anxious attention.

The boy was lying at the bottom of the bed with his head raised on pillows, and his legs supported by his attendants: totally insensible; his eyelids closed; and when they were opened the pupils were seen dilated, and did not contract on the approach of light; his countenance bloated and of a livid colour; his jaw firmly closed; his trunk and limbs extended to the utmost and perfectly rigid; his respiration slow, laborious, and loudly stertorous; his pulse slow, regular, and rather feeble; the heat of his skin natural. In a very few minutes he became agitated by convulsions of the trunk and of all the limbs, so violent that it was with difficulty that four or five persons could keep him upon the bed. The muscles of the left side were rather more affected by them than those of the right. The alternation of these convulsions, with a state of rigid extension of the limbs, and a forcible bending of the head and body backwards, may, with the above-mentioned symptoms, serve to describe his situation, with very little change, for at least four successive hours; after which the rigidity abated, and the convulsions became less frequent and less severe.

One of the gentlemen present since informed me, that, when he first saw the boy, and for seven or eight minutes, as he thinks, afterwards,

there was not the smallest appearance of life, neither pulse, respiration, motion, nor any degree of sensibility to what must otherwise have given him pain, as the falling of particles of burning tobacco blown upon the face with pipes, with which they were throwing the smoke of it towards his eyes and nostrils. The first sign of life was a very slow and weak pulse in the wrist, which became perceptible before any respiration took place; and he thinks that this last did not occur till within a very few minutes of my seeing him.

My first step was to take away quickly, by a large orifice, about twelve ounces of blood from the arm. I did not open either of the jugular veins, having heretofore found that, however easy it is to open them, they are not always so easily to be closed again; and in this instance I was particularly glad that I had not done it, because, in spite of every care to prevent such an occurrence by adhesive plaster, long bandages, &c. &c. the bleeding from the arm, in consequence of the patient's strong muscular exertions, was often renewed; and could only be restrained by constant and long continued pressure, in a degree which it might have been highly injurious to apply to the neck. Some favourable change in his countenance ensued upon the loss of blood, but that was all: the other symptoms were unaltered. I then endeavoured to excite the action of vomiting, and for this purpose, with much difficulty, and at the expence of one of the poor fellow's teeth, I introduced the pipe of a metal funnel into his mouth, and poured in a solution, first of zincum vitriolatum, and afterwards of cuprum vitriolatum, small quantities of which only were swallowed at a time, but enough ere long to produce repeated and copious vomitings, whereby we ascertained clearly that his stomach had been overcharged. Soon afterwards we were able to act freely and forcibly upon the intestines by means of a clyster of infusion of tobacco.

These were the measures, repeating them as they appeared necessary, which were principally resorted to for the first two hours; during which time, notwithstanding some advantages evidently gained, the patient's recovery appeared very doubtful. His countenance was somewhat improved, and his pulse a little more free; but the coma and stertor remained: the trismus and convulsions had not been lessened: the iris continued insensible to light; and at times the extremities became cold, the pulse feeble, and the powers of life seemed to be giving way. After persevering in our efforts, however, for some time longer, a relief of the symptoms became more apparent; and by the end of about three hours more, it was evident that a considerable change for the better had taken place: the pulse was now more frequent and full; the respiration more easy; the permanent spasm had greatly subsided, and the convulsive paroxysms occurred seldomer, and were much slighter; the boy appearing in the intervening periods to be only very soundly asleep, with a fainter kind of snoring; the pupil began to contract on the approach of light; the power of swallowing also was restored in a considerable degree, of which we availed ourselves first of all to provoke vomiting again (an effort by which he always discharged a quantity of undigested food; and appeared proportionally relieved), and afterwards to throw in a little warm brandy and water, and some diluted sal volatile. In this last interval of three hours, besides vomiting and purging, we applied cupping-glasses, with the scarificator to the back of the neck and

shoulders; the clyster of tobacco smoke (which, however, notwithstanding the apparatus worked perfectly well, appeared to do nothing); volatile alkali to the temples, nostrils, and fauces; and such other expedients of less moment as occured to us.

At length, we had the satisfaction of perceiving the recovery of our patient advance more rapidly, though it was not till after eight or nine hours that his convulsions entirely left him; and still longer before his speech and senses returned. Leeches were afterwards applied to the temples: he remained sleepy, having only intervals of sense throughout the succeeding day and night. On the next following day, Monday, he was pretty well restored, being then capable of taking his food readily, and of holding a conversation with me, from which I attempted, in vain, either to trace in his mind any recollection of what had passed since his retiring to bed with his fellow-servant on the Saturday night (this he remembered), or to collect from him any motive by which he had been induced to perpetrate the horrid deed that had so nearly cost him his life. It has since been intimated, I understood, that his father (not now living) had formerly shewn some signs of insanity; but nothing of this sort had ever been observed in the boy.

Remarks by Dr. Addington.

How far the circumstances of this case may serve to throw any additional light on the immediate cause of death in these occurrences, I shall not presume to determine.

It will, I suppose, be admitted, that the leading symptoms were of the apoplectic character; and those which cannot strictly be considered as apoplectic, at least denoted the morbid affection to have its seat in the brain, or other sensorial organs. Whether this affection was produced in the first instance principally by the suspension of respiration from compression of the trachea by the cord, or by its pressure on the large vessels in the neck, or by both conjointly, it is not easy to say. The boy's breathing appears to have been totally stopped for a time, though it cannot be ascertained exactly how long: the attendants imagined eight or ten minutes, if not more. The probability, I think, is, that it was not so long, since this function returned spontaneously, or without the use of any means which could be thought to have the power of re-exciting it: besides, respiration was not the first symptom of returning life that made its appearance, a weak pulsation having been previously felt in the wrist. Another circumstance to be noticed is, that the recovery of the patient did not quickly ensue on the restoration of the motion of the heart and lungs; which would appear to be usually the case in resuscitation after drowning. Now, the several writers on the subject of suspended animation, differing as they do from each other on the proximate cause of death (one attributing it to the presence of black blood in the left side of the heart; another, to an affection of the brain; another, to collapse of the lungs, and the want of latent heat in the blood; another, to the privation of vital air), all admit that there is a very close analogy in the symptoms and appearances on dissection, whatever be the mode in which it is effected, whether by submersion, strangulation, or suffocation; and agree in referring it principally to the stoppage of respiration in the first instance.

Mr. Kite himself, who considers apoplexy as the proximate cause of

death, either apparent or real, from these accidents, regards it, even in hanging, not so much the effect of compression of the vessels by the cord, as of the accumulation of blood, first in the right side of the heart, in consequence of the cessation of motion in the lungs; and then, of course, in the venæ cavæ, and jugulares. Accordingly, we are advised to direct our efforts to the restoration of the function of the lungs, in the expectation that, if this be once restored, the other symptoms will yield of course. "No sooner," says Fothergill, "is the vital air excluded, than respiration is suspended, the passage of the blood through the lungs is intercepted, and of course through the whole system. The action of the heart being impeded by the same cause, the circulation is suppressed. The brain, unsupported by the circulation, being unable to exert its influence, the mental and corporeal actions cease, and the mind is no longer conscious of the state of the body." This is his account of the manner in which life is gradually extinguished. In another place, he describes that of its restoration, thus: "If at this period," *i. e.* when the animal is apparently dead, "the lungs in due time are inflated with air, in imitation of the natural respiration," (much more then, when natural respiration itself returns spontaneously) "the dark-coloured blood begins to resume its florid hue, the heart to renew its motion, weakly indeed at first, but by degrees more powerfully, till, at length, the brain recovers its functions, and life is completely restored."

I have met with but few details of the particular appearances and treatment in cases of strangulation. But there are two which exhibit a considerable resemblance to the foregoing, particularly in the circumstance of the continuance or spontaneous return of the respiration. The first is given by Mr. Kite, and ended fatally: the other by Mr. Hey, of Leeds, with a happier termination. Mr. Kite's account is as follows:

"A middle-aged man hung himself: after hanging, it was supposed from three to five minutes, he was cut down. He was senseless and speechless; but his pulse, respiration, and power of deglutition, still remained. A surgeon was sent for, who blooded him, and left him some medicine. I saw him about an hour and half after the accident, at which time he was in a deep apoplectic fit, attended with all the most violent symptoms of that strongly-marked disease. As he had been drinking, several emetics were exhibited, and purgatives given both by the mouth and rectum, but they did not produce the least effect. The pulse being large and soft, made me dubious as to the propriety of another general bleeding; cupping-glasses, therefore, were applied to the head and breast, and three or four ounces were drawn off by their means; frictions and stimulants were likewise had recourse to, but, after lying three or four hours, nature was no longer able to maintain the unequal conflict.

"The next day the body was opened. The dura mater adhered very firmly to the inside of the skull, and it required considerable force to separate them. On removing the dura mater, the vessels of the pia mater did not appear more distended than usual; but I afterwards thought there was a larger proportion of blood in the vessels of the brain in general than I had observed in others. There was no inflammation on this membrane; but at that part of it which was immediately below the junction of the coronal with the sagittal suture, it adhered to the dura mater on each side the longitudinal sinus: these adhesions were

easily separated; the intervening substance was white, and about the dimensions of a silver three-pence. The same appearance was found in the middle portions of the membrane which cover the cerebellum and pia mater, uniting them together. The brain in general was firmer than common," &c. &c.

The account concludes with mentioning the condition of the thoracic and abdominal viscera, which were sound.

Mr. Hey's case is thus related:

"In the evening, Mr. —— being greatly distressed, on account of some disagreeable circumstances in business, rashly hanged himself. He was discovered by his son soon after the commencement of his suspension, and, on being cut down, shewed some signs of life. A surgeon, who lived near him, was immediately sent for; who finding him lying insensible, and frothing at the mouth, and not being informed of the cause of these symptoms, took about a pound of blood from the arm. Soon after the evacuation, Mr. —— was seized with convulsions. A blistering plaster was then applied betwixt the shoulders; and some spirit of hartshorn was sent, with directions to give a little in water, whenever it could be got down. When the convulsions had continued an hour, without intermission, I was desired to visit the patient, having attended the family in ordinary for some years.

"I found him lying on a bed, which was placed on the chamber floor, near an open window. He was insensible, and violently convulsed. His hands and feet were cold; the rest of his body was hot, and in a profuse perspiration. He was held down by five or six stout men, to prevent any injury to himself from the violent and almost incessant agitations which he suffered.

"I was of opinion, that these convulsions were the effect of debility, brought on by the suspension, and probably increased by the copious evacuation of blood. I determined, therefore, to give him some stimulating medicines as soon as he could swallow them," &c.

The account goes on to state the good effects of warmth and cordial treatment, with wine and volatile tincture of valerian, &c. which it is not necessary to recite.

In both these instances it appears that, notwithstanding the quick and spontaneous return of the respiration, if indeed it had ever been completely suspended, other symptoms of a very serious kind continued for many hours; and in one of them went on to a fatal termination: the other, which ended more happily, is adduced by Mr. Hey, to shew what he considers the mischievous effects of bleeding, and the benefit of stimulating remedies.

Waving, for the present, the consideration of these opinions, I shall only remark the resemblance of both these cases to that of Horsel; and the confirmation which I think they afford to the idea that the brain, or sensorial organs, are more concerned in the injury primarily produced by these occurrences, than some of our latest writers on the subject have supposed; at least, that they are so in the case of hanging: and if there be as much similarity as is alleged in the effects of the various modes of destroying life before mentioned, perhaps there is more foundation for Mr. Kite's opinion of apoplexy being generally the proximate cause of death, than has recently been admitted.

The negative of this opinion seems to have been deduced rather from

the results of experiments made on animals killed for this purpose, and afterwards examined; than from the symptoms actually attending a state of suspended or recovering animation in the human subject. It is true, indeed, the examination of human bodies after death has not tended to confirm the notion of apoplexy; but it is at the same time to be observed, that the nature of diseases of the brain, or sensorial organs, is by no means always to be detected by such examinations. There is every reason to believe that many of these diseases, not excepting apoplexy itself, frequently exist, without producing any of those changes of mechanical structure which are obvious to our senses, and to which they have been attributed. A writer of very considerable sagacity and great experience attributes these affections more frequently to the state of the nerves of the stomach, or the nervous system generally, than to that of the substance of the brain; and has cited many instances of complete and fatal apoplexy, where there was no extravasation, or other cause of compression within the skull. And Dr. Cullen, though he adopts the doctrine of compression, yet thinks it probable "that this disorder does not always depend upon that cause, but sometimes upon a certain state of immobility of the nervous powers, produced by certain circumstances in the nervous system itself, which seems to be communicated from one part of the body to another."

With respect to experiments upon animals, there is one distinction which I think has not been sufficiently attended to in the conclusions drawn from them as to the seat and nature of particular morbid affections; which is this: that whilst such conclusions as relate merely to visible and obvious deviations from the natural healthy structure and condition of parts may be perfectly accurate, those, on the contrary, which involve, in any degree, the state of vital power, or nervous sensibility, are always liable to objection. Thus, for instance, in an animal that has been hanged or drowned, it is very easy to ascertain whether the brain be free from compression by extravasated fluid, or its vessels free from any extraordinary degree of distension: but to conclude from thence that the morbid affection occasioned by such hanging or drowning did or did not partake of the nature of apoplexy, or other disease of the sensorial organs, is not so satisfactory. Neither should we be justified in the inference, that because the carotids or jugulars of a dog may be tied without inducing fatal mischief, that therefore a compression or complete obstruction of those vessels may suddenly, and yet safely, take place in the human subject.

I shall just add a few observations on the remedies which were employed in the above stated case.

I am well aware that at the present day bleeding from the arm in any quantity is by no means commonly recommended on these occasions: and I have not hesitated to adduce one case which has been published by a most respectable surgeon in proof of what he considers the mischievous effects of this practice. Nevertheless, I acknowledge I have my doubts of the theory on which this opinion is founded; and these doubts are not removed by the evidence of the case alluded to. Mr. Hey's opinion is, that convulsions in those cases are purely the effect of debility; and, in the instance stated, that they were the immediate consequence of venesection. To this opinion, the following considerations may justly be opposed:

1. That convulsions are very commonly met with in the progress of

recovery from these accidents, and that where neither bleeding nor any other debilitating remedies have been employed.

2. That these convulsions take place, when the powers of life are sensibly returning; not, therefore, when the debility is greatest.

3. That in Mr. Kite's case, where the debility, if such it was, terminated in death, convulsions did not happen, although the patient had been bled.

4. That, in the case of Horsel, the convulsions took place before the opening of the vein; and although they were not sensibly relieved by it, yet they gradually gave way under the use of other evacuating and debilitating remedies, and had partly ceased before any cordials or stimuli had been employed; the pulse in the meantime acquiring strength and freedom.

On the whole, is it not probable that the convulsions in these cases are to be considered less as the effect of general debility, than of a violent derangement of the sensorial functions, in consequence of a sudden change in the condition of the brain; or more properly of what Dr. Kirkland calls the brainular system? Wherein precisely this change consists, I do not profess to understand: it is very remarkable that these convulsions, though not perhaps signs of, are certainly attendants on recovery from these accidents. Is it unreasonable then to conjecture that they may be occasioned by the impetus of the circulation now restored in the vessels of a most delicate organ in which it has for a time been suspended? If there be any truth in this theory, bleeding, instead of being injurious, may prove beneficial, by lessening the force of that renewed circulation whereby the exquisite organization and sensibility of the brain and nerves are deranged. It is true the only visible effect of it in my patient was a change in the colour of his face and expression of his countenance; but this change was favourable, and led on to other symptoms of amendment.

In Mr. Kite's case the patient was also bled, but this appears to have been the only efficient remedy employed for some time. If after bleeding, he was left in the hands of common attendants, on whom it depended to administer, in circumstances of peculiar difficulty, the medicines prescribed; or, if those medicines, though duly given, were not of a more active kind than such as are usually employed for the evacuation of the stomach and intestines, it is not surprising that they should fail of success. The dissection of this case clearly exhibits congestion within the skull, and supplies another argument against Mr. Hey's notion of debility: the man, as before observed, had been bled, yet no convulsions followed.

The other remedies employed in the case of Horsel, at least the most active of them, I mean the emetics and clysters of tobacco, will likewise fall under the censure of those who regard debility as the leading feature in similar affections.

Nothing however was more apparent to all the by-standers as well as to myself, than the relief which the sufferer manifested after their operation; the degree of such relief being always proportioned to the activity of the medicine. It may perhaps be alleged, that this relief may be accounted for from the peculiar circumstance of the patient's stomach having been overloaded previous to strangulation. Be it so. This circumstance ought to be allowed all its proper weight; but even then surely, this single circumstance will not be deemed of sufficient import-

ance to determine the general propriety of exhibiting powerful emetics and cathartics in these cases. At any rate, if these medicines are likely to prove injurious in all other instances, this particular circumstance justifying or requiring their exhibition, as an exception to the common rule, would be a subject of so much regret that we ought never to proceed upon it, but upon the most certain proof of its existence. In my patient, though suspected, it was not previously known, and was only demonstrated by the action of the emetics themselves.

But if it be true, as there is surely some reason to believe, that not debility, but an affection of the brainular system, similar to that which obtains in nervous apoplexy, be the real condition, and constitutes the chief danger of these unhappy patients; may we not appeal to the well-known efficacy of those remedies which excite powerfully the action of the primæ viæ, followed and assisted by stimulants and cordials, in relieving such affections, to support this practice?

After all, it is by no means the design of the author of this paper to attempt to establish on the basis of a single case, any particular doctrine concerning the treatment of these melancholy accidents; but merely to state the facts, with such observations upon them as presented themselves, for the consideration of those who have had more experience in this branch of medical pathology.

Case of Recovery from Drowning, by W. Whitworth, Esq. and Mr. T. P. Smith, jun.

DEAR SIR, *Cornhill, May* 28, 1808.

On Wednesday evening last, about six o'clock, in my ride home through the Green Lanes to Hornsey, I observed when I was about 100 yards distant from the New River Bridge (which is parallel with what is called the Eel Pie House), something floating, or rather bobbing up and down, which I imagined to be a dog that had been skinned, therefore did not hurry, but was guarding my horse from startling; but, when I came to the bridge, to my amazement, it was the face of a man, and who appeared struggling in the last agonies of death. I immediately dismounted and flew to his relief, and, with the help of kind Providence, I succeeded in getting him out. I was entirely alone, and it must have been full ten minutes before any person came up to me, during which time I turned him upon his face, then upon his back, and moved him about as well as I could, by which he discharged a great deal of water. I begged the persons who had now come up to wait by him (as there was not a moment to be lost) while I rode to procure a conveyance, but just as I was mounting, a distant car came in sight, into which we put him, and had him taken to the Weavers' Arms, Newington Green. What followed you have herewith, in Mr. Smith the surgeon's account. With great respect, I am, Dear Sir, Your most obedient servant, W. WHITWORTH.

To the Treasurer of the Royal Humane Society.

DEAR SIR, *Stoke Newington.*

I have the pleasure to communicate to you a successful case of recovery from suspended animation occasioned by drowning. It occurred on Wednesday 27th of May 1808, in Mr. Lill, of Church-street, Bethnal Green, aged 65 years; who was taken out of the New River, and

carried to the Weavers' Arms, Newington Green, at which place I shortly after saw him: he was totally senseless, and to all appearance dead; but after a vigorous application of the means recommended by the Humane Society for about twenty minutes, I had the satisfaction to observe symptoms of returning life; encouraged by this success, our efforts were continued, and in less than one hour the man was completely recovered.

Much merit is due to Mr. Whitworth for his humane attention in rescuing Mr. Lill, as also to Edmund Watson, of Hangers' Lane, near Tottenham, and George Sturges, servant to Messrs. Davis and Marsh, distillers, Cold Bath Fields. I have the honour to be, Sir, your humble servant,

THOMAS SMITH, jun. Surgeon.

Case of Recovery from Drowning, communicated by Mr. Teasdale.

SIR, *Merchant Taylors' Hall.*

During the recent midsummer holidays, my eldest son, who is just nine years old, together with one of his school-fellows, master Wathen, was on a visit at his grand-mother's, Mrs. Guthrie, Cannon-court, near Leatherhead. Mrs. G. had, at the same time, another of her grandchildren, master John Burrows, at her house.

These three little fellows, viz. my son, Wathen (who is about twelve years old), and little Burrows (who is about seven), went to see the mowers in an adjoining meadow, but soon wandered from them up the river side, to the distance of about half a mile up the Mole, into which river (unperceived by Wathen and my son) little Burrows fell; hearing a noise, as that of a large fish jumping, the two boys turned towards the river, where they saw their comrade Burrows with only the top of his hat and his hands visible above the surface.

With admirable presence of mind (as if it were by previous concert, and without saying a word to each other), both Wathen and Teasdale ran to his assistance. Wathen first seized the bough of an impending bush, and Teasdale followed his example; but they could not reach Burrows until their own bodies were more than half over the bank of the river.

Wathen first caught hold of one of Burrow's hands, and my son afterwards got hold of the other, but they had got such an imperfect hold, that they were obliged to use great management and skill, by one relieving the other, until they at last got such a purchase as enabled them to drag the little sufferer from what (but for the presence of mind and adroitness of these little fellows) must have proved his watery grave.

Little Burrows lay on the grass senseless, and without any apparent sign of life, for upwards of five minutes, after which he gradually came to his senses, and was supported to his grand-mama's by his two preservers.

I need not point out to the intelligent and industrious managers of your institution, that the merit of these little fellows is considerably enchanced by their promptness in taking immediate and efficient measures to save their little comrade, without running for aid to the house or the mowers in the adjacent meadow. I have the honour to be, Sir, your most humble servant,

RICHARD TEASDALE.

To the Treasurer of the Royal Humane Society.

Of the ingenious contrivances for the furtherance of these humane objects, it would be impossible to convey any idea equal to that impressed by actual inspection; and the implements themselves may be examined at the various establishments for furthering the purposes of the Humane Society.

Some Account of Mr. Daniel's Life-preserver.

Though this contrivance is not original, it deserves encouragement. The body of the machine, which is double throughout, is made of pliable water-proof leather; large enough to admit its encircling the body of the wearer, whose head is to pass between two fixed straps, which rest upon the shoulder; the arms of the wearer pass through the spaces on the outside of the straps; one on each side, admitting the machine under them to encircle the body like a large hollow belt; the strap on the lower part of the machine is attached to the back of it, and by passing betwixt the thighs of the wearer, and buckling, holds the machine sufficiently firm to the body, without too much pressure under the arms. The machine being thus fixed, is inflated with air by the bearer blowing from his lungs, through a cock affixed to the machine, a sufficient quantity of air to fill the machine, which air is retained by turning the stop-cock. The machine, when filled with air, will displace a sufficient quantity of water to prevent four persons from sinking under water.

CHAP. XXIII.

BREWING AND DISTILLING.

BREWING.

The art of brewing, or of preparing a vinous fermented liquor from farinaceous seeds, is very ancient. It was known to the ancient Egyptians, Germans, Spaniards, Gauls, and the inhabitants of the British isles, and the north of Europe. The liquor made by them, however, resembled more our sweet and mucilaginous ales, the use of hops being of modern invention.

The vinous fermentation cannot be produced without saccharine matter; and any substance containing sugar is capable of producing ardent spirit, or alkohol.

Barley is a grain consisting of fecula or starch, albumen, and a little gluten; and by the process of malting, its fecula is converted into sugar: hence it affords a convenient material for the production of alkohol, which is the substance that gives the intoxicating quality to every liquor.

Malting, or the converting barley into malt, is the first process in the making of beer. To effect this, the grain is put into a trough with water, to steep for about three days: it is then laid in heaps, to let the water drain from it, and afterwards turned over and laid in new heaps. In this state, the same process takes place as if the barley were sown

in the ground. It begins to germinate, puts forth a shoot, and the fecula of the seed is converted into saccharine matter. When this is sufficiently accomplished, which is known by the length of the shoot (about $\frac{2}{3}$ of the length of the grain), this process of germination must be stopped, otherwise the sugar would be lost, nature intending it for the nourishment of the young plant. The malt is therefore spread out upon a floor, and frequently turned over, which cools it, and dries up its moisture, without which the germination cannot proceed. When it is completely dried, in this manner, it is called air-dried malt, and is very little altered in colour. But when it is dried in kilns, it acquires a brownish colour, which is deeper in proportion to the heat applied; it is then called kiln-dried. This malt is then coarsely ground in a mill.

Mashing is the next step in the process of brewing. This is performed in a large circular wooden vessel, called the mash tun, shallow in proportion to its extent, and furnished with a false bottom, pierced with small holes, and fixed a few inches above the real bottom. There are two side openings, in the interval between the real and false bottom: to one is fixed a pipe, for the purpose of conveying water into the tun, and the other for drawing the liquor out of it. The malt is to be strewed evenly over the false bottom of the same tun, and then, by means of the side pipe, a proper quantity of hot water is introduced from the upper copper. The water rises upwards through the malt, or as it is called the grist, and when the whole quantity is introduced, the mashing begins, the object of which is to effect a perfect mixture of the malt with the water, so that the soluble parts may be extracted by it: for this purpose, the grist is sometimes incorporated with the water by iron rakes, and then the mass is beaten and agitated by long flat wooden poles, resembling oars, which are either worked by the hand or by machinery.

When the mashing is completed, the tun is covered in, to prevent the escape of the heat, and the whole is suffered to remain still, in order that the insoluble parts may separate from the liquor: the side is then opened, and the clear wort allowed to run off, slowly at first, but more rapidly as it becomes fine, into the lower or boiling copper.

The chief thing to be attended to in mashing, is the temperature of the mash, which depends on the heat of the water, and the state of the malt. If the water was let in upon the grist boiling hot, the starch which it contains would be dissolved, and converted into a gelatinous substance, in which all the other parts of the malt, and most of the water, would be entangled beyond the possibility of being recovered by any after process.

The most eligible temperature appears to be from 185° to 190° of Fahrenheit; for the first mashing, the heat of the water must be somewhat below this temperature, and lower in proportion to the dark colour of the malt made use of. For pale malt the water may be 180°, but for brown it ought not to be more than 170°.

The liquor or wort (as it is called) of the first mashing is always by much the richest in saccharine matter; but to exhaust the malt, a second and third mashing is required, in which the water may be safely raised to 190° or upwards.

The proportion of wort to be obtained from each bushel of malt depends entirely on the proposed strength of the liquor. It is said that 25 or 30 gallons of good table-beer may be taken from each bushel of

malt. For ale and porter of the superior kinds, only the produce of the first mashing, or six or eight gallons, is to be employed.

Brewers make use of an instrument called a sacchrometer, to ascertain the strength and goodness of the wort. This instrument is a kind of hydrometer, and shews the specific gravity of the wort, rather than the exact quantity of saccharine matter which it contains.

The next process in brewing is the boiling and hopping. If only one kind of liquor is made, the produce of the three mashings is to be mixed together; but if ale and table-beer are required, the wort of the first, or first and second mashings is appropriated to the ale, and the remainder is set aside for the beer.

All the wort destined for the same liquor, after it has run from the tun, is transferred to the large lower copper, and mixed with a certain proportion of hops. The better the wort, the more hops are required. In private families a pound of hops is generally used to every bushel of malt; but in public breweries, a much smaller proportion is deemed sufficient. When ale and table-beer are brewed from the same malt, the usual practice is to put the whole quantity of hops in the ale wort, which having been boiled some time, are to be transferred to the beer-wort, and with it to be again boiled.

When the hops are mixed with the wort in the copper, the liquor is made to boil, and the best practice is to keep it boiling as fast as possible, till upon taking a little of the liquor out, it is found to be full of small flakes like that of curdled soap. The boiling copper is in common breweries uncovered; but in many, on a large scale, it is fitted with a steam-tight cover, from the centre of which passes a pipe, that terminates by several branches in the upper or mashing copper. The steam therefore produced by the boiling, instead of being wasted, is let into the cold water, and thus raises it very nearly to the temperature required for mashing, besides impregnating it very sensibly with the essential oil of the hops, in which the flavour resides.

When the liquor is boiled, it is discharged into a number of coolers, or shallow tubs, in which it remains until it becomes sufficiently cool to be submitted to fermentation. It is necessary that the process of cooling should be carried on as expeditiously as possible, particularly in hot weather; and for this reason, the coolers in the brew-houses are very shallow. Liquor made from pale malt, and which is intended for immediate drinking, need not be cooled lower than 75 or 80 degrees; of course this kind of beer may be brewed in the hottest weather; but beer brewed from brown malt, and intended to be kept, must be cooled to 65° or 70° before it is put into a state of fermentation. Hence in the spring, the month of March, and in autumn, the month of October, have been deemed the most favourable for the manufacture of the best malt liquor.

The last operations in brewing are the tunning and barrelling. From the coolers the liquor is to be transferred into the working tun, and with it is to be mixed a gallon of yeast to four barrels of beer, in order to excite the vinous fermentation. In four or five hours the fermentation begins, and it requires from 18 or 20 hours to 48, before the wort is fit to be put into the barrels, which may be regarded as finishing the process: and it may be fined in the usual way, by isinglass, yolks of egg, or a portion of gum-tragacanth.

Additional receipts in Brewing.

Cheap and easy Method of Brewing.—One bushel of malt, and three quarters of a pound of hops will, on an average, brew twenty gallons of good beer.

For this quantity of malt, boil twenty-four gallons of water; and having dashed it in the copper with cold water to stop the boiling, steep the malt (properly covered up) for three hours; then tie up the hops in a hair cloth, and boil malt, hops, and wort, altogether, for three quarters of an hour, which will reduce it to about twenty gallons. Strain it off, and set it to work when lukewarm.

In large brewings this process perhaps would not answer, but in small ones, where the waste is not so great, and where the malt can be boiled, the essence is sure to be extracted.

To make excellent and wholesome Table Beer.—To eight quarts of boiling water put a pound of treacle, a quarter of an ounce of ginger, and two bay leaves; let this boil for a quarter of an hour, then cool, and work it with yeast, the same as other beer.

Uses of Ground Ivy in Ale, &c.—The leaves thrown into the vat with ale clarify it, and give it an antiscorbutic quality. The expressed juice mixed with a little wine, and applied morning and evening, destroys the white specks on horses' eyes.

To make Ginger Beer.—To every gallon of spring water add one ounce of sliced white ginger, one pound of common loaf sugar, and two ounces of lemon juice, or three large table-spoonfuls; boil it near an hour, and take off the scum; then run it through a hair sieve into a tub, and when cool (viz. 70°) add yeast in proportion of half a pint to nine gallons; keep it in a temperate situation two days, during which it may be stirred six or eight times; then put it into a cask, which must be kept full, and the yeast taken off at the bung-hole with a spoon. In a fortnight add half a pint of fining (isinglass picked and steeped in beer) to nine gallons, which will, if it has been properly fermented, clear it by ascent. The cask must be kept full, and the rising particles taken off at the bung-hole. When fine (which may be expected in twenty-four hours) bottle it, cork it well, and in summer it will be ripe and fit to drink in a fortnight.

To make Yeast or Barm.—Mix two quarts of soft water with wheat flour, to the consistence of thick gruel, or soft hasty pudding; boil it gently for half an hour, and when almost cold, stir into it half a pound sugar, and four spoonfuls of good yeast. Put it into a large jug, or earthen vessel, with a narrow top, and place it before the fire, so that it may, by a moderate heat, ferment. The fermentation will throw up a thin liquor, which pour off and throw away; the remainder keep for use in a cool place in a bottle, or jug tied over. The same quantity of common yeast will suffice to bake or brew with. Four spoonfuls of this will make a fresh quantity as before.

Substitute for Barm or Yeast.—[This receipt was presented to the October Meeting of the Manchester Agricultural Society, held at Altringham, 1809, by Charles Lownds, Esq. when it was ordered that a copy should be printed for each member.]

Boil two ounces of hops in four quarts of water twenty minutes; strain it, and whilst hot stir in half a pound of flour; when milk-warm, mix half a pint of good ale yeast, or a pint of this mixture, which you should always reserve to keep a supply. When nearly cold, bottle and

cork it well, and keep it for use in a cool place; if too warm it would be apt to fly; you will judge of this by the season of the year; observe to fill the bottles only two-thirds full.

When used, put of it into the flour you intend to make into bread, in the proportion of a pint to twenty-four pounds, with water to make it of a proper warmth; mix a little of the flour with it in the middle of the mug, or kneading vessel; it must be covered close, and set in a tolerably warm place all night. Knead it well in the morning, and let it stand some hours longer to rise. It should be eighteen or twenty hours from the first putting together, before your bread is set into the oven.

To make Yeast in the Turkish manner.—Take a small tea-cup full of split or bruised peas, and pour on it a pint of boiling water, and set it in a vessel all night on the hearth, or any warm place. The next morning the water will have a froth on it, and be good yeast, and will make as much bread as two quartern loaves.

Easy Method of preserving Yeast.—Yeast may be preserved for a considerable time, by coating a board with a whiting-brush, allowing the coat to dry; then putting on another, which is in like manner to dry; and so a third, and any number of successive coatings, which, when perfectly dry, will keep vigorous for a long time. Another method is to whisk the yeast until it becomes thin, and then to lay it upon a dry platter or dish, repeatedly, with a soft brush as above-mentioned. The top is then to be turned downwards to keep out the dust, but not the air which is to dry it. By this method it may be continued till it be two or three inches thick, when it may be preserved in dry tin canisters for a long time good. When used for baking, a piece is to be cut off and laid in warm water to diffuse or dissolve, when it will be fit for use.

To make Artificial Yeast.—Boil potatoes of the mealy sort till they are thoroughly soft; skin and mash them very smooth, and put as much hot water as will make the mash of the consistency of common beer yeast, and not thicker. Add to every pound of potatoes two ounces of coarse sugar or treacle, and when just warm, stir in it for every pound of potatoes two spoonfuls of yeast; keep it warm till it has done fermenting, and in twenty-four hours it may be used. A pound of potatoes will make about a quart of yeast, and when made will keep three months. Lay your bread eight hours before you bake it.

N. B. Instead of water and sugar in the above receipt, beer has been used, not bitter nor strong, in the same proportion, and with equal if not better success.

Usefulness of the common Hazel-nut in Brewing.—In countries where yeast is scarce, it is a common practice to take the twigs of hazel, and twisting them together so as to be full of chinks, to steep them in the ale-yeast during its fermentation; they are then hung up to dry, and at the next brewing they are put into the wort instead of yeast. In Italy the chips are frequently put into turbid wine, for the purpose of clearing it, which is effected in twenty-four hours.

To prevent Beer from growing flat.—In a cask, containing eighteen gallons of beer, becoming vapid, put a pint of ground malt, suspended in a bag, and close the bung perfectly; the beer will be improved during the whole time of drawing it for use.

To recover sour Beer.—When beer is become sour, add thereto some

oyster shells, calcined to whiteness, or, in place thereof, a little fine chalk or whiting. Any of these will correct the acidity, and make it brisk and sparkling; but it should not be long kept after such additions, otherwise it will spoil.

To restore pricked or stale Beer.—To about a quart of stale beer, put half a tea-spoonful of salt of wormwood; this will restore the beer, and make it sparkle when poured into a glass, like bottled porter.

DISTILLATION.

The objects of distillation, considered as a trade distinct from the other branches of chemistry, are chiefly spirituous liquors, and those waters impregnated with the essential oils of plants, commonly called simple distilled waters. The distilling of compound spirits and waters is reckoned a different branch of business, and those who deal in that way are commonly called rectifiers. This difference, however, though it exists among commercial people, is not at all founded in the nature of the thing; compound spirits being made, and simple spirits being rectified, by the very same operations by which they are first distilled, or at least with very trifling alterations. See *Chemistry*.

The great object with every distiller ought to be, to procure a spirit perfectly flavourless, or at least as well freed from any particular flavour as may be; and in this country the procuring of such a spirit is no easy matter. The only materials for distillation that have been used in large quantity, are malt, and molasses or treacle. Both of these, especially the first, abound with an oily matter, which, rising along with the spirit, communicates a disagreeable flavour to it, and from which it can scarcely be freed afterwards by any means whatever.

Previous to the operation of distilling, those of brewing and fermentation are necessary. The fermentation ought always to be carried on as slowly as possible, and performed in vessels closely stopped, only having at the bung a valve pressed down by a spring, which will yield with less force than is sufficient to burst the vessel. It should even be suffered to remain till it has become perfectly fine and transparent; as by this means the spirit will not only be superior in quantity, but also in fragrance, pungency, and vinosity, to that otherwise produced.

With regard to performing the operation of distilling, there is only one general rule that can be given, namely, to let the heat in all cases be as gentle as possible. A water-bath, if sufficiently large, is preferable to any other mode, and will perform the operation with all the dispatch requisite for the most extensive business. As the end of rectification is to make the spirit clean as well as strong, or to deprive it of the essential oil as well as the aqueous part, it will be proper to have regard to this even in the first distillation. For this purpose, the spirit, as it first comes over, should be received into a quantity of cold water; as by this means the connection between it and the oily matter will be considerably lessened. For the same reason, after it has been once rectified in the water-bath, it should be again mixed with an equal quantity of water, and distilled a second time. Thus the spirit will be freed from most of the oily matter, even though it has been very much impregnated with it at first. After the spirit has been distilled once or twice in this manner from water, it may be distilled in a water-bath

without any addition; and this last rectification will free it from most of the water it contains.

For the distillation of compound spirits, the following practical rules will amply suffice, and will at the same time afford a competent view of the general process.

In rectifying and distilling compound goods, a smaller still is known to make a cleaner and better commodity than one that is larger; and one that is half a hogshead gage, over and above your hand-breadth depth from the edge or top of your still, is accounted the fittest size for a moderate trade; both as it may be managed without fatigue, and as it produces encouraging profit much superior to the fund it requires. When you erect and place your still, and other utensils, let it be if possible in a building, out-house, or shed, separate from, but nearly adjoining to, your dwelling-house or shop, to prevent any hazard which may arise by fire, to which all spirituous goods are liable; and no otherwise to be extinguished but with a woollen blanket or rug, drenched in water, and cast upon the flame, which extinguishes it by excluding the air. Let the work-house be large enough, not only in regard to your still, worm-tub, and pump, which must be all placed in a row, or ranged together, to contribute to your working with ease and pleasure, but because your spirits which are for distilling must lie in some proper place or part of your work-house, to be near at hand to charge your still with, and at some reasonable distance from the fire: and also that you may have room enough for placing all your empty vessels, tubs, cans, and other utensils properly belonging to the distilling trade, to have them near at hand on all occasions; and let your still-house floor be paved with broad stones or flags, having a descent to carry off all the wash from your still, your hot liquor from the worm-tub, and other occasional slops, which will be made by washing your casks, &c. by which your still-house floor will always be kept clean. They are usually kept in a cistern underneath, and pumped up as wanted. It is absolutely necessary, that there be sufficiency of water where your pump is to be sunk, both to keep your worm-tub continually cool, to make up all your goods to their proper strength, and to serve all other occasions whatsoever: it matters not whether your water be soft or hard, if you have plenty of it.

Your still must be placed upon brick-work, having an ash-hole of 24 inches long, nine inches broad; and to the iron bars, where your fire is to be under your still, 21 or 22 inches high; made somewhat sloping, the better to command the ashes. When the brick-work is made about the height last mentioned, you must place your grate-door (both of strong iron) before, or in the front of the stove, or place, where your fire is to be made under your still. The iron door and frame must be about ten inches long, and eight inches broad; close behind the door and frame must be placed two cross iron bars, about two inches and a half broad, half an inch thick, and 15 or 16 inches long; both ends of which bars must be laid about three inches into the brick-work, for fixing them the better; and the upper part of it must be about half an inch lower than the upper edge of the door-frames. Just behind the said two iron bars must be placed another flat iron bar, about an inch and a half broad, half an inch thick, and sixteen inches long, fastened in the brick-work as the former, and near an inch lower: upon which last-mentioned flat iron bar, your iron grate must rest at the higher

end; and the other ends of your iron grate must rest upon another flat iron bar of the same dimensions, fastened at the furthest end, or most distant part of your still-bottom. The iron grate must consist of about eight bars of inch-square iron, but exactly of one length, made broad, or flatted diagonally, at each end, to rest on the two cross iron bars, so that the upper of the square bars must be even with the higher part of the flat iron bars on which they rest, that the fire-shovel, or coal-rake, may run smoothly along them. The square iron bars must be about eighteen inches long, and laid loose within an inch-breadth of each other upon the two broad iron bars, as firm as you can, yet so that they may be put in, or taken out, as occasion requires; then raise your brick-work, so that your still-bottom, when fixed or rested upon it, may be about 10 or 12 inches above the iron grate, that the fire may have room to play; and the part of the brick-work under the still, where the fire is placed, and as far as it extends within the stove, must be inlaid with hearth inch-tiles, or fire-brick, well fastened with such mortar as will abide the fire much longer than common bricks. Let not the fire-place be too broad, wherein your workman's judgment will have regard to the sides not being of the same thickness with the bottom of your still. There must be left a sloping place, or hole, proper for conveying the smoke into the flue and round the still into the chimney; which flue must be carried up a convenient height, to draw the smoke, and carry it off. Let your still-cock come so far through the brick-work, that your wash may run out either into cans, or otherwise, as you have conveniency for conveying it away. The brick-work about your still must be exactly round, as high as the upper nails of your still, sloping from the flame lest any liquor boil over, and very well mortared, and covered all round with coarse canvas or hop-sack, to keep the fire closer in, the wall from cracking, and your clothes from being injured, and the flue must be plaistered well within.

Your worm-tub must be placed very near your still, upon a strong wooden frame according to the size of your tub, which must be six or eight times the capacity of your still, so that every stave of the tub may rest firmly upon the frame, the better to support the great weight of such a quantity of water as is necessary to keep the worm constantly cold, or cool enough. Your worm-tub frame must be so high, that when the tub is placed upon it, the low end of your worm which comes through the worm-tub, will admit of your cans being readily placed under, and taken away when they are full. The upper end of your worm must be placed so, that the arm of your still-head may go into it, without any difficulty, and shut in so close as to be easily luted; and your worm-tub must stand so upright, that no liquor may hang in the worm; which you may know, by putting a pint or quart of water into the worm, which will run out at the lower end of it. In the middle of your worm-tub you may place a wooden gutter three or four inches square within, to reach from the top of the worm-tub to the bottom of the same, having about three or four inches on the opposite sides at the bottom end of it left open, that the fluid that is pumped into the gutter, which descends, may flow out at the two breaches to the lower part of the worm-tub; which forces all the hot water to ascend upwards, and runs either over the worm-tub, or rather through a leaden pipe of a moderate size, which is called a waste pipe, being put through and soldered in your worm-tub, and extended down your

tub-sides to what further length you please, to convey the warm water from your tub, till the liquor in your worm-tub is perfectly cold; which by the continuance of your still working will grow hot again and again, and must be still cooled after the same manner. The water conveyed in by a lead pipe at the bottom is still better. Your pump must be placed next your worm-tub, and of such a height that you may have a spout or cock put into that part of your pump which is next your worm-tub, under which you may fix a good gutter, to reach to, and be led into, the gutter that is fixed in the middle of your worm-tub, that the liquor may be more easily, and with less waste, conveyed into your worm-tub, in order to cool it. You must have also another spout or cock in the fore-part of your pump, much lower than the other, for drawing water for all common uses; the higher spout being closed, and only appropriated for cooling the liquor when hot in the worm-tub.

It will be necessary also to have a large back, set upon a strong frame, to command the worm-tub, and to contain a large quantity of water, having a large brass cock communicating with the still, &c. to draw off what water you may stand in need of suddenly; which may be of very great service to you upon any emergency; and may be drawn off in much less time, and with less trouble, than by pumping; for the still may accidentally be sometimes dry, and prove of dangerous consequence, if you had not a quantity of water ready on all occasions in your back to repair to. Your water-tub must be open at the upper end, that you may dip or drench your cans into it, or lay any small rundlets in it to steep and become tight; and that your tub may be more easily filled with water.

You will find your interest in keeping a good middle-sized press, placed in a corner of your still-house, and fixed so steadily as not to be moved when you use it; having a very strong bed or place, in which the goods to be pressed are put, and five or six hair-cloths, somewhat broader than your press, to be put betwixt every layer of elder-berries, cherries, raspberries, or any other things which are to be pressed; all which are to be laid as thin as possible, and your press-screw to be drawn pretty much, till the liquor run by a spout made of sheet-lead, nailed to the fore-part of the bottom of your press, into one of your cans, which must be placed under it, to receive the juice from the press, and draw out your iron-pin, to give time to the press to empty itself of what juice lies in the bed; then draw the screw a little closer, and allow time for the juice to run out, and so more and more, till all the juice is wholly drawn or pressed out of the goods.

You must have also, at least, three or four iron-bound open-headed tubs, wide at the top, and narrower taper-wise down to the bottom, (one of these tubs is to contain two puncheons or pipes of goods, another to contain one pipe, and another a hogshead) which must be placed orderly in your still-house, and now and then filled with hot liquor out of your still; and the iron hoops driven, or fastened, to keep them firm, and in fit condition to hold the goods that are to be put or made up in them. Likewise three or four iron-bound cans, either with iron round hands or bales; one to hold five, another to contain four, another three, and, if you please, another two gallons; not by bare measure to the top, but let your goods reach no higher than a brass mark placed therein, determining the measure to which the liquor must rise.

Another necessary utensil is an iron-bound wood funnel, which by computation would hold three or four gallons, with a strong iron nosel or pipe to put into the bungs of the casks which the goods are to be put in, which must be ranged or placed upon a shelf along with the iron-bound cans pretty near your still.

In some convenient part of your still-house, where room may be most spared, must be placed a pretty large vessel, either covered or open, with a cock in it, in which you must put all your feints or after-runings, until you have a quantity worth your distilling over; into which vessel or cask you may put the washings out of your casks, the drippings of your cocks, any goods accidentally spoiled, either by wrong mixture, spilling on the ground, or otherwise, or any thing else that has a spirituous matter or substance in it. Another piece of necessary furniture for your still-house, and which cannot be dispensed with, is a good strong copper or tin pump, of about five feet long, and six inches in circumference, its nosel about six inches from the top of the pump, and the nosel about fourteen inches long from the body of the pump; besides a little angular nosel about four inches, to be put on upon the other, or taken off as your occasions require. The use of this pump, with its appurtenances, is to draw off your spirits out of the pieces into your cans to charge your still with; and for many other similar purposes in which it will be serviceable.

A pewter crane or siphon is also absolutely necessary, made somewhat semilunar, or like a half-moon or angle, about six feet and a half from one end to another, and four inches round about on the outside, to draw goods out of any vessel where the pump cannot play. A pewter valencia is likewise useful, being about two feet long, tapering at the end, which you put into the piece, or any other vessel, to draw out any small quantity, by putting or moving your finger on the upper side of the valencia, whereby the liquor enters, for your tasting or trying its proof; which, with the crane, may be hung against the wall.

Hippocrates's bag, or flannel-sleeve, is another thing very necessary for the distiller, whereby all bottoms of casks, though ever so thick and feculent, by putting into this bag or sleeve to filtre, become presently clear, the porous parts of the bag being soon filled with the grosser matter; and the thin or liquid element running clear from the bag, and as good as any of the rest: also any foul goods or liquor may presently be made clear and fine, by putting some powdered alabaster into the goods or liquor, or sprinkling the same on the bag to stop up its pores, by which they presently become or run clear, leaving nothing but the sediment or gross matter in the bag; nor do the goods or liquor contract the least ill flavour from the alabaster powder. This bag or sleeve is made of a yard or ell of flannel, not over-fine or close-wrought, laid sloping, so as to have the bottom of it very narrow, and the top as broad as the cloth will allow, well sewed up the side, and the upper part of the bag folded about a broad wooden hoop, and well fastened to it; then boring the hoop in three or four places, it may be suspended by a cord.

You must have for your still-fire a large poker, fire-shovel, and coal-rake, with other necessary utensils for your still-house; a cooper's hand-saw, adze, gimlet, a striking gimlet, a hammer, a pair of scratching-irons, a pair of tarriers, a bung-borer, a box-foreset, and a box of bungs.

When you are to distil, you are to make ready, against your still is charged, a paste of the size of a turkey-egg, made half of Spanish wheat,

and the other half of rye-meal, bean-meal, or wheat-flour, well mixed together, and made into a paste with water, of the consistence of an ordinary paste for baking; and having put on your still-head, with its nose in the upper end of the worm, then take your paste, working and making it pliable with the heat and operation of your hands, and spread it upon the junctures of the body and head of your still, and that part of the arm of your still-head which goes into the end of the worm, to keep in the goods from boiling over: make the paste very smooth, by wetting your hand (with which you lay on the paste) in water, to cause it to lie the closer, and secure the goods from all mischances; and reserve a piece of paste, about the size of a small apple, lest the lutting should crack or break out, which is very dangerous, and must therefore be carefully attended to and examined, and in case of any defect, mended with the paste reserved for that purpose.

When you set up a new still, which has not been used, let it be filled, within your hand-breadth of the brim, with water, and put to it a peck of wheat-bran; and put the head upon the still, and fix it firmly on with a wooden bar, about the thickness of your wrist, upon the loop, a little below the neck of your still, and the upper end of the wooden bar must be fastened under some beam or lentel perpendicularly, to prevent the still-head from moving by the force of distillation; then lute your still as directed in the foregoing paragraph; and having made a fire under it proper for that purpose, draw off two, three, or four gallon-cans by distillation, by which all the joints and nails of your still will be cemented, and made fit for distilling your strongest-proof goods; then damp or extinguish your fire with some wet ashes; wash your still-head and worm; afterwards you may charge and work your still with what goods you please.

All your spirits to be distilled should be proof goods, which you may try by having a small quantity put into a glass phial, and shaking it with your hand; if the blebs or proof of it continues a pretty while upon the top or surface of the goods, it is then what is called proof goods; and when it is distilled, it will yield about, or very near, two-third parts, or every thirty gallons will distil to nearly, and sometimes full, twenty gallons, according as the spirits are higher or lower proof; which you may make proof, or to what strength and weakness you please, by adding what proportion or quantity either of spring or river water is necessary; as for example, take and observe this general rule in distilling, that all double goods coming from the still, clear proof and without feints, must be made up with liquor, to that quantity you charged your still with at first: as if with thirty gallons of proof-spirits, it will yield about twenty gallons of high-proof goods, the deficiency of ten gallons must be made up with water, till the whole amounts to thirty gallons, your first charge; and in single goods you add one and a half part more of water (viz. fifteen gallons) to what is ordered in double goods, whereby you will have in all forty-five gallons of single goods; but if your spirits are below proof, upon shaking the phial, or glass, the goods will fall flat, or the blebs or proof will not continue on the surface of it; and according to the degree of its being reduced more or less below proof, the goods will flatten accordingly; and when such goods are distilled, they will fall short in quantity; and upon making them proof, and no otherwise, will you know what body they were of, and how far they were reduced, except by the hydrometer.

When your still is charged with goods for distilling, and luted, then make your fire under the still, which, if possible, must be of coals, because their heat is most constant and durable, and wood fires are very subject to both extremes, of too much or too little heat, which are prejudicial, and sometimes hazardous. Let the fire at first be moderate, and then by degrees increased, and now and then stirred up with your poker, as is usual in common fires; and by laying your hand upon the body of your still, as the fire gains strength in the stove or furnace under the still, you will by moderate degrees ascend up your still-head, occasioned by the goods in the still boiling higher and higher. When your still-head becomes warm or hot, then prepare a damp (which is to check or lessen the violence of the fire); which damp is made of about half a bushel of ashes, taken from under the stove or furnace, and two or three gallons of water cast upon and well mixed with them, upon the ground or hearth, before or under your kiln-door, to be ready to cast upon the fire when there is occasion; and move your hand upon the still, higher and higher, as you find the heat grow hotter, and ascend to the neck of your still-head, which, when it comes with any vehemence more than a common warmth, to turn downwards towards the worm-end, in which the arm of the still is luted, cast three or four fire-shovels of wet ashes upon the hottest part of the fire, which must be done very smartly and critically, at the very turning of the highest part of the swan-like neck of your still towards the still, by which the violence of the fire is abated, which would otherwise bring down the goods through the worm very foul in a rushing stream, which is dangerous, and by all means to be prevented; whereas your damping the fire seasonably, brings down the liquid like a small twine thread.

You must take especial care not to touch or meddle with your fire while your still is near coming to work, because of increasing or heightening the heat, which would unavoidably make your still run foul; but when your fire is damped and come to work, you may let your kiln-door be shut close, and continue so, as long as the worm runs as small as a moderate large turkey quill. But as the kiln-door being long shut will overcome the damp, and bring the fire to its former violence, so when you are apprehensive of it, you may throw open the kiln-door, which abates the heat immediately, and lessens the stream flowing from your worm; and you must cautiously meddle with your still-fire until more than one or two cans be come off from your still, which is about double the strength of the first goods, and then there is less danger, and you may more safely stir up or mend your fire, or shut your kiln-door, to make your goods come down with a little larger stream, until the goods be wholly come off from the still.

When you perceive near two-third parts of the first quantity which you put into your still to be run from thence, then be often tasting the goods, which must run as long as any strength remains; when all the goods are come off, the former clear colour of them will turn to a blue, and sometimes, according to the nature of the goods, a whitish colour, which are phlegmatic and foul, and if they were suffered to run amongst the spirit, would make it taste disagreeably, but by being kept by themselves, the goods are clean and well tasted; and the feints, or after-runnings, being put and kept in a vessel until you have a quantity together, you may then distil them. When the strength of the spirit is gone, or run off, take away your can of goods, and let the feints run

into another can, as long as the feints will burn on the still-head, being cast thereon, and a candle or lighted paper put to it to try the experiment.

When your feints are drawn into spirits, which must be made proof, that you may make a better judgment how to convert them to other goods, you must always make them into such goods as carry a very predominant or prevailing gust or taste, above other ingredients; and therefore the common and usual method taken with them is, to convert them into aniseed or wormwood cordials, putting a little more than the receipt of ingredients which is made use of, the same goods being drawn from clean malt spirits, and also dulcifying a little higher than otherwise, purposely to cleanse or carry off any ill relish contracted from the multiplicity of mixtures in the feints.

You must always keep the water in the worm-tub very cool, that the goods coming off the still may be perfectly so, which will contribute to bettering the spirits, and making them settle sooner; whereas the goods coming off warm or hot from the still, they lose considerably of their strength, which is extracted by the hot liquor, become more palatable, and not without much time and difficulty are made fine.

When you distil any goods which are not above one-third or one-half of the quantity your still will work, be sure you add one, two, or three cans of water to the goods you charge your still with, both for better preserving the still from damage, and because the goods will cleanse and fine themselves, by having a quantity of water with them wrought together, and will run considerably more from the still than when it is charged with full-proof goods; not that they can possibly be more in strength or substance, but by their being weakened with water put to them, are drawn lower, and require less fluid to make them proof.

When you draw off your still more than once a day, if your second distillation is of the same goods with the first, and the quantity of each the same, then when your goods and feints are drawn off, damp your fire very well under your still, draw the wash quite out, and, without cleaning out the ingredients, you may charge it a second time with the spirits and ingredients, and draw off your goods as at other times; but if you charge your still a second time with the same goods, and no greater quantity than what the goods run from what your still was first charged with, then, when your goods are come off, and without suffering the feints to run, damp your fire, strike off your still-head, and charge your still accordingly with your ingredients, and draw them off as you do at other times; but if you charge your still a second time the same day with goods different from, and of another sort than, what your still was first charged with, then clean it of all the wash and ingredients, scrape off all the luting on the still-head and upper part of the body of your still, which remained or was left on the still-head; wash down the worm with about a gallon of liquor, to prevent all obstructions; and draw off your goods of the second charging or distillation, as you do at other times; the process not differing either in drawing off or making up the goods from what you do when your still is charged with no other goods, or only one distillation made at that time.

Be sure that betwixt every new charging of your still you scrape off all the paste or luting which cleaves or is burned to the still-head, or the brim of your still, which might endanger your new luting to crack

or break, was it put upon the old paste or luting; and also let your worm be constantly washed down with a gallon of water, lest any thing be accidentally got into the worm, which might prove of the worst consequence, and must therefore be prevented or guarded against by the greatest caution you can possibly take.

It conduces to meliorate compound spirits, when the ingredients of which they are made are infused in spirit over-night, before they are distilled; which spirit must cover the ingredients, and being measured, you must allow what they measured out of the quantity you put into your still, so that both the spirits in which the ingredients are infused, and the other which you measure into your still, must together make up the intended quantity; and let all your ingredients, according to their several kinds, be bruised, sliced, or otherwise separated, before their infusion, if you have time and opportunity.

Take particular care that no manner of grease, tallow, soap, or any other unctuous matter, get or fall into your pieces, tubs, rundlets, or cans; because they injure the proof of the goods, and although their strength should be very high, yet they will apparently fall as flat as water, and then their strength can only be ascertained by the hydrometer. Above all things, beware of lighted candles, torches, papers, or other combustible matter, being brought too near your still, or any vessel where your goods are contained, which are subject to take fire upon very slight occasions. You must take care to have your stove-chimney and flue often swept or cleaned; both to prevent the danger of its taking fire, and to make your flue, or kiln-chimney, draw the better, whereby your stove-fire will be first lighted, and afterwards continued, with less trouble.

It is best, for preserving the strength and flavour of your goods, that as they come off your still into your cans, exactly filled up to the mark of a four or five gallon measure, they be emptied into the casks they are to be kept in; always noting, or keeping an account of, the several cans or quantity of goods to be put by; which must be made up to their several proportions, according to the quality or kind of goods so to be made up; which is, or must be, by adding so much liquor or pump-water as completes the same. And in dulcifying your goods, first weigh the sugar you intend to put in; then dissolve it in one or more cans of the water with which you make up your goods; bruising all the lumps of the sugar, and stirring it very well with a rummager in your cans, till all is dissolved: and then emptying it into your other goods; and mixing all well together, by drawing off several cans of the goods at the cocks, and putting them in again at the bungs; and then rummage all well together, till they are perfectly well mixed and compounded.

When you have made up your goods to the quantity and quality you intend, that they may become fine and clear; all your goods which are made proof will without any art or composition settle, and become fine and clear, within one or two days at most; but goods that are reduced below proof, the weaker they are made in strength, the longer they are in becoming fine or saleable. To every hogshead of Geneva, or strong waters, put five or six ounces of alum powdered so as to go through a coarse hair-sieve, and mixed in three or four gallons of the goods, well stirred or dissolved in your cans; and then put to your whole quantity, rummaged and very well stirred together, some cans of goods being

drawn off, and put to the goods again, to mix them the better; and the Geneva will be clear in one day, and the other in two or three days.

When your distilled goods are finished, being set upon a stillyon or pair of guntrees, in order to their being drawn off, you must let the bungs of the casks continue open, till they become fine and fit for use: then you may put the bungs in, but not too hard, and set a foreset or a plughole, and a foreset or plug put slightly, in a proper place of your casks, to take out or loosen, to give vent when you draw off any goods: it is a vulgar error to suppose that goods are materially injured or weakened by the bungs being left open: for where there is any quantity of goods of any tolerable body or strength, they receive no manner of injury from it, but mellow and clear more and more by having good vent either by bung or foreset.

You may make any goods deeper or lighter coloured, by dulcifying with browner or finer sugar. And as all common goods bear a low price, they are always sweetened with the cheapest brown sugars, which commonly make them of a deep amber colour; which by long custom and usage has so prevailed with the populace, that goods of a lighter colour, occasioned by being dulcified with better sugar, are less accounted of; whereas fine goods, which are generally drunk by persons of judgment and distinguishing palates, must be made up with fine sugars; and the clearer and lighter colour they are, the more acceptable and valuable to those who know what they buy; and some persons are so nice this way, as to dulcify with loaf-sugar; but the sugars in your receipts specified are what will give a general satisfaction to all your customers.

When you first draw off any goods lately distilled, that which lies next the cork will not be clear, or left fine, according as the goods have been a longer or shorter time distilled; and must be set aside till you have drawn off what fine goods you have present occasion for; and then you may put what you first drew in at the bung, and it will settle in a very little time; and when any of your standard or other casks are near out, or to be emptied or drawn off, let all the bottoms be drawn into one of your cans, and first put one, two, or three gallons of water, according to the size of your cask, to wash out the cask; and let your first water with which the cask is washed be put among your feints; and what water you wash clean out with must be cast away; then take your can of bottoms, and first hanging up your flannel sleeve in some convenient place, put your bottoms into it all at once, if your bag will hold it. The first runnings of the bag will be foul, till all the porous parts of the bag are filled up with the sediment that is amongst the bottoms of the casks; and when they run fine, you may take away the foul goods, and put a clean vessel to receive the fine spirits; and when the bag is run nearly out, you may put in it what goods first run foul when the bottoms were put into the bag, and let the bag hang till all the goods be quite run off from the sediment, which must then be cast away, but the fine goods, so filtred through the flannel sleeve, will be as good and wholesome as any of the rest; and the bottoms of fine goods, which are much more valuable, must be filtred, or put through blotting-paper, folded in four parts, one part or leaf to be opened funnelwise, and made capable to receive what it will hold of the bottoms being put into the upper part of a large tin funnel: which will filtre off all the goods from the sediment.

When you are to buy any brandies or spirits, do not consent to take

them by measure; but having tasted and tried them in a phial, insist upon having them by weight, at seven pounds three quarters to each gallon, and the stronger spirits will be lighter than what is reduced.

It may not be here improper to insert some certain rules observed by distillers in drawing off and making up their distilled goods: viz. when you perceive about two-third parts of the first quantity you put into your still is come off, then be often trying your goods in a glass or phial; and when you see that the bell, or proof, immediately falls down and does not continue a good while on the surface, then take away the can of goods, and substitute another vessel to receive the feints; which, if suffered to run among the goods, would cause a disagreeable relish, and be longer in fining down: whereas the feints being kept separate, the goods will be clean and well tasted, when made up with liquor to their due quantity.

It will much improve your goods, to throw into your still along with your goods, when first charged, about six ounces of bay salt to every ten gallons of spirit; and so proportionably, more or less, to a greater or less quantity of spirits; by this means the goods will better cleanse themselves and separate from their phlegmatic parts, and the spirits so dephlegmated will ascend and come over much cleaner and finer in distillation.

One very great desideratum among distillers of this country is, a method of imitating the foreign spirits, brandy, rum, gin, &c. to a tolerable degree of perfection; and notwithstanding the many attempts that are daily made for this purpose, the success in general has been but very indifferent. The general method of distilling brandies in France differs in nothing from that practised here in working from malt-wash or molasses; nor are they in the least more cleanly or exact in the operation. They only observe more particularly to throw a little of the natural ley into the still along with the wine, as finding this gives their spirit the flavour for which it is generally admired abroad. But though brandy is extracted from wine, experience tells us, that there is a great difference in the grapes from which the wine is made. Every soil, every climate, every kind of grapes, varies with regard to the quantity and quality of the spirit extracted from them. A large quantity of brandy is distilled in France during the time of the vintage; for all those poor grapes that prove unfit for wine, are usually first gathered, pressed, their juice fermented, and directly distilled. This rids them of their poor wines at once, and leaves their casks empty for the reception of better. It is a general rule with them not to distil wine that will fetch any price as wine; for in this state the profits obtained are vastly greater than when reduced to brandies. The large stock of small wines, with which they are almost over-run in France, sufficiently accounts for their making such vast quantities of brandy in that country more than in others which lie in warmer climates, and are much better adapted to the production of grapes. Nor is this the only source of their brandies; for all the wine that turns eager is also condemned to the still. and, in short, all that they can neither export nor consume at home, which amounts to a large quantity; since much of the wine laid in for their family provision is so poor as not to keep during the time of drawing from the cask. Hence our English spirits, with proper management, are convertible into brandies that shall hardly be distin-

guished from the foreign in many respects, provided the operation is neatly performed.

The best, and indeed the only method of imitating French brandies to perfection, is by an essential oil of wine; this being the very thing that gives the French brandies their flavour. It must, however, be remembered, that in order to use even this ingredient to advantage, a pure tasteless spirit must first be procured; for it is ridiculous to expect that this essential oil should be able to give the agreeable flavour of French brandies to our malt spirit, already loaded with its own oil, or strongly impregnated with a lixivious taste from the alkaline salts used in rectification.

To prepare the oil of wine, take some cakes of dry wine-lees, such as are used by our hatters, dissolve them in 6 or 8 times their weight of water, distil the liquor with a slow fire, and separate the oil with a separating glass, reserving for only the nicest uses that which comes over first, the succeeding oil being coarser and more resinous. Having procured this fine oil of wine, it may be dissolved in alcohol; by which means it may be preserved a long time fully possessed of all its flavour, but otherwise it will soon grow rancid.

With a fine essential oil of wine thus procured, and a pure and insipid spirit, French brandies may be imitated to perfection. The essential oil, however, must be drawn from the same kind of lees as the brandy to be imitated was procured from: *e. g.* in order to imitate Coniac brandy, it will be necessary to distil the essential oil from Coniac lees; and the same for any other kind of brandy. For as different brandies have different flavours, and as these flavours are entirely owing to the essential oil of the grape, it would be preposterous to endeavour to imitate the flavour of Coniac brandy with an essential oil procured from the lees of Bourdeaux wine. When the flavour of the brandy is well imitated by a proper dose of the essential oil, and the whole reduced into one simple and homogeneous fluid, other difficulties are still behind: the flavour, though the essential part, is not, however, the only one; the colour, the proof, and the softness, must also be regarded, before a spirit that perfectly resembles brandy can be procured. With regard to the proof, it may be easily accomplished, by using a spirit rectified above proof; which, after being intimately mixed with the essential oil of wine, may be let down to a proper standard with fair water: and the softness may, in a great measure, be obtained by distilling and rectifying the spirit with a gentle fire; and what is wanting of this criterion in the liquor when first made, will be supplied by time: for it must be remembered, that it is time alone that gives this property to French brandies, they being at first acrid, foul, and fiery. But with regard to the colour, a particular method is required to imitate it to perfection, which may be effected by means of treacle or burnt sugar. The treacle gives the spirit a fine colour, nearly resembling that of French brandy; but as its colour is dilute, a large quantity must be used. This is not, however, attended with any bad consequences; for notwithstanding the spirit is really weakened by this addition, yet the bubble-proof, the general criterion of spirits, is greatly mended by the tenacity imparted to the liquor by the treacle. The spirit also acquires from the mixture a sweetish or luscious taste, and a fulness in the mouth; both which properties render it very agreeable to some palates. A much smaller quantity of

burnt sugar than of treacle will be sufficient for colouring the same quantity of spirits: the taste is also very different; for, instead of the sweetness imparted by the treacle, the spirit acquires from the burnt sugar an agreeable bitterness, and by that means recommends itself to many who are offended with a luscious spirit. The burnt sugar is prepared by dissolving a proper quantity of sugar in a little water, and scorching it over the fire till it acquires a black colour. Either treacle or burnt sugar will nearly imitate the genuine colour of old French brandy; but neither of them will succeed when put to the test of the vitriolic solution.

The spirit distilled from molasses or treacle is very pure. It is made from common treacle dissolved in water, and fermented in the same manner as the wash for the common malt spirit. But if some particular art is not used in distilling this spirit, it will not prove so vinous as malt spirit, but more flat and less pungent and acid, though otherwise much cleaner-tasted, as its essential oil is of a much less offensive flavour. Therefore, if good fresh wine-lees, abounding in tartar, are well fermented with molasses, the spirit will acquire a much greater vinosity and briskness, and approach much nearer to the nature of foreign spirits. Where the molasses spirit is brought to the common proof-strength, if it is found not to have a sufficient vinosity, it will be very proper to add some dulcified spirit of nitre; and if the spirit is clean worked, it may, by this addition only, be made to pass on ordinary judges for French brandy. Great quantities of this spirit are used in adulterating foreign brandy, rum, and arrack. Much of it is also used alone in making cherry-brandy and other cordials by infusion; in all which, many, and perhaps with justice, prefer it to foreign brandies. Molasses, like all other spirits, is entirely colourless when first extracted; but distillers always give it as nearly as possible the colour of foreign spirits.

If these principles hold good, the imitation of foreign spirits of all kinds must be practicable; if we only procure some of those substances from which the spirit is drawn, and distil it with water, the essential oil will always give the flavour desired. Thus to imitate Jamaica rum, it will only be necessary to procure some of the tops, or other useless parts, of the sugar-canes, from which an essential oil being drawn, and mixed with clean molasses spirit, will give it the true flavour. The principal difficulty must lie in procuring a spirit totally, or nearly, free from all flavour of its own. The spirit drawn from the refuse of a sugar-house has been commended as superior to that drawn from molasses; though it is very probable, that to procure an absolutely flavourless spirit is impossible. The only method, therefore, of imitating foreign spirits is, by choosing such materials as will yield a spirit flavoured as much like them as possible; and the materials most recommended, and probably the best that can be used, are raisins.

We shall subjoin the genuine process of preparing Holland gin, agreeably to the practice of the best Dutch distillers. Their grist is composed of ten quarters of malt, ground considerably finer than our malt-distillers' barley-grist, and three quarters of rye-meal; or, more frequently, of ten quarters of rye and three quarters of malt-meal. The ten quarters are first mashed with the least quantity of cold water it is possible to blend it up with; when uniformly incorporated, as much boiling water is added as forms it into a thin batter; it is then put into

one, two, or more casks, or gyle-tuns, with a much less quantity of yeast than is usually employed by our distillers. Generally on the third day they add the malt or rye meal, previously made into a kind of lob, prepared in a similar manner, except in not being so diluted; but not before it comes to the temperature of the fermenting wash; at the same time adding full as much yeast as when at first setting the backs.

The principal secret in the management of the mashing part of the business is, in first thoroughly mixing the malt with the cold water, and in subsequently adding the due proportion of boiling water, that it may still remain sufficiently diluted after the addition of the fine meal, under the form of lob, and in well rousing all together in the back, that the wash may yet be dilute enough for distilling, without endangering its burning to the bottom of the still. Thus they commodiously reduce the business of brewing and fermenting to one operation. By using cold water to uniformly wet the malt, all danger of clogging the spending of the tap would be necessarily avoided; but here is no occasion to do any thing more than sufficiently dilute the wash, consisting of the whole of the grain, thin enough to be fermented and distilled together, by which means the spirit of the bran and husky part, as well as of the flour of the grain, are completely extracted, yet their wash, compared with ours, is about three-eighths thinner. For these reasons, they obtain more spirit from their grain than we do, and of a better quality, with not half the trouble taken by our distillers. The gravity of the distillers' wash at Weesoppe, in the neighbourhood of Amsterdam, in 1774, was but eighteen pounds per barrel, very little more than half the gravity of ours. Their stills are usually from three to five hundred gallons each; they constantly draw off three cans of phlegm, after the runnings cease to burn on the head of the still, when distilling wash; and five cans when distilling low wines; a practice we are unacquainted with, as we usually draw our fire as soon as the runnings from the still burn languidly on the still-head. This, and the great quantity of rye they use, cause their spirit to be so much more acid; and the diluteness of their wash is a very good reason for the greater purity of their spirit; though most writers mistakingly say, our spirit is much cleaner.

Rectification into Holland Gin.—To every twenty gallons of spirit of the second extraction, about the strength of proof spirit, take three pounds of juniper-berries, and two ounces of oil of juniper, and distil with a slow fire until the feints begin to rise, then change the receiving can; this produces the best Rotterdam gin. An inferior kind is made with a still less proportion of berries, sweet fennel-seeds, and Strasburgh turpentine, without a drop of juniper-oil. It, and a better sort, but inferior to the Rotterdam gin, are made at Weesoppe. The distillers wash at Scheedam and Rotterdam is still lighter than at Weesoppe, where there were about three hundred distillers formerly in 1774.

Receipt for 140 *Gallons of Gin made without Distillation.*

Take 100 gallons of proof malt spirits, rectified by agitation; infuse two pounds and an half of the best juniper-berries for a week or ten days; then take of oil of turpentine, three ounces; oil of juniper-berries, five ounces; oil of sweet fennel-seeds, two ounces; fill these essential oils with some dry loaf sugar, and dissolve them in three pints of spirit

of wine that will fire gunpowder: add them to the 100 gallons of spirits and juniper-berries, rousing them well up for an hour; next day make up to one in five, with lime water, and sweeten with a quarter of an hundred of clayed sugar. Fine with eight or ten ounces of alum dissolved in two or three gallons of the making-up water reserved for the purpose. These ingredients will make 140 gallons of as good English gin, as any usually made by distillation.

Preparation of Rum in the West Indies.

In the still-house, as well as the boiling-house, the greatest cleanliness is necessary: the vats, at the beginning of the crop, ought to be well washed out, both with warm and cold water, to divest them of any sour stuff which may have accumulated or adhered to their bottoms and sides since they were last in use; and if every vat, just before the first setting, or mixing the liquor in it, were to be rinsed with a little rum, I can venture to say, the distiller would be amply repaid for this trifling expense and trouble.

In setting the first round of liquor, a greater proportion of skimming from the sugar-pans must be used than will afterwards be necessary, as the distiller has no good lees, and very little molasses to add to the mass; and besides, the skimmings at this time are not so rich as they will be some time hence; that is, in March, April, and May, which are esteemed the best yielding months. The following proportions will succeed well in the beginning: for every one hundred gallons your vat contains, put forty-five gallons of skimmings, and five gallons of molasses, to fifty gallons of water.

When you have got good lees, or returns, as they are commonly called, mix equal quantities of skimmings, lees, and water, and for every one hundred gallons add ten gallons of molasses.

When the mill is going, and therefore you have no skimmings, mix equal parts of lees and water, and for every hundred gallons add twenty gallons of molasses.

From liquor set in these proportions, the distiller may expect to obtain from ten to fifteen per cent. of leeward islands proof rum, and twice as much low-wines.—But the quantity of spirit will depend greatly on the quality of the ingredients, and in some measure on the weather; therefore an intelligent distiller will vary his proportions accordingly.

The Distillation of Rum in the West Indies.

Rum differs from what we simply call sugar spirit, as it contains more of the natural flavour, or essential oil, of the sugar-cane; a great deal of raw juice, and even parts of the cane itself being often fermented in the liquor, or solution, of which the rum is prepared.

From hence it is generally thought, that the rum derives its flavour from the cane itself.

Some, indeed, are of opinion, that the oily flavour of the rum proceeds from the large quantity of fat used in boiling the sugar.

This fat, indeed, if coarse, will give a rancid flavour to the spirit in our distillations of the sugar liquor, or wash, from our refining sugar-houses at home; but this is nothing like the flavour of rum.

Great quantities of rum are made at Jamaica, Barbadoes, Antigua, and other sugar islands. The method of making it is this:

When a sufficient stock of materials is got together, they add water

to them, and ferment them in the common method, though the fermentation is always carried on very slowly at first; because at the beginning of the season for making rum in the islands, they want yeast, to make it work; but after this, they, by degrees, procure a sufficient quantity of the ferment, which arises up as a head to the liquor in the operation; and thus they are able afterwards to ferment, and make their rum with a great deal of expedition, and in very large quantities.

When the wash is fully fermented, or to a due degree of acidity, the distillation is carried on in the common way, and the spirit is made up proof, though sometimes it is reduced to a much greater degree of strength, nearly approaching to that of alkohol, or spirits of wine; and it is then called double distilled rum.

It would be easy to rectify the spirit, and bring it to a much greater degree of purity than we usually find it to be of, if it did not bring over in the distillation so large a quantity of the gross oil, which is often so disagreeable, that the rum must be suffered to lie by a long time to mellow before it can be used; whereas, if well rectified, its flavour would be much less, and consequently much more agreeable to the palate.

The best state to keep rum, both for exportation and other uses, is doubtless in that of alkohol, or rectified spirits. In this manner, it would be contained in half the bulk it usually is, and might be let down to the common proof strength with water when necessary.

Sugar Spirit.

We mean, by a sugar spirit, that extracted from the washings, skimmings, dross, and waste of the boiling-house. These drossy parts of the sugar are to be diluted with water, fermented in the same manner as molasses or wash, and then distilled in the common method. And if the operation be carefully performed, and the spirit well rectified, it may be mixed with foreign brandies, and even coniac, in a large proportion, to great advantage; for this spirit will be found superior to that extracted from treacle, and consequently more proper for these uses. In Barbadoes a very good spirit of this kind is prepared from the cane juice, called cane spirit, resembling very pure rum.

Raisin Spirits.

By raisin spirit, we understand that extracted from raisins, after a proper fermentation.

In order to extract this spirit, the raisins must be infused in a proper quantity of water, and fermented.

When the fermentation is completed, the whole is to be thrown into the still, and spirits extracted by a strong fire.

The reason why we here direct a strong fire is, because by that means a greater quantity of the essential oil will come over the helm with the spirit, which will render it much fitter for the distiller's purpose; for this spirit is generally used to mix with common malt goods: and it is surprising how far it will go in this respect, ten gallons of it being often sufficient to give a determining flavour, and agreeable vinosity, to a whole piece of malt spirit.

In the same manner a spirit may be obtained from cyder. But its particular flavour is not so desirable as that obtained from raisins.

To improve the Flavour of Malt Spirits.

The flavour of malt spirits is said to be highly improved, by putting three ounces and a half of finely powdered charcoal, and four ounces and a half of ground rice, into a quart of spirits; and letting it stand during fifteen days, frequently stirring it; then let the liquor be strained, and it will be found nearly of the same flavour as brandy.

Expeditious Method of distilling simple Waters.

Tie a piece of muslin, or gauze, over a glazed earthen pot, whose mouth is just large enough to receive the bottom of a warming-pan; on this cloth lay your herb, clipped, whether mint, lavender, or whatever else you please; then place upon them the hot warming-pan, with live coals in it, to cause heat just enough to prevent burning, by which means, as the steam issuing out of the herb cannot mount upwards, by reason of the bottom of the pan just fitting the brim of the vessel below it, it must necessarily descend, and collect into water at the bottom of the receiver, and that strongly impregnated with the essential oil and salt of the vegetable thus distilled; which, if you want to make spirituous or compound water of, is easily done, by simply adding some good spirits, or French brandy to it, which will keep good for a long time, and be much better than if the spirits had passed through a still, which must of necessity waste some of their strength. Care should be taken not to let the fire be too strong, lest it scorch the plants; and to be made of charcoal, for continuance and better regulation, which must be managed by lifting up and laying down the lid, as you want to increase or decrease the degrees of heat. The deeper the earthen pan, the cooler the season; and the less fire at first (afterwards to be gradually raised), in the greater perfection will the distilled water be obtained.

As the more moveable, or volatile parts of vegetables, are the aqueous, the oily, the gummy, the resinous, and the saline; these are to be expected in the waters of this process; the heat here employed being so great as to burst the vessels of the plants, some of which contain so large a quantity of oil, that it may be seen swimming on the surface of the water.

Medical waters thus procured will afford us nearly all the native virtues of vegetables, and give us a mixture of their several principles, whence they in a manner come up to the expressed juice or extract gained therefrom: and if brandy be at the same time added to these distilled waters, so strong of oil and salt, a compound, or spirituous water, may be likewise procured at a cheap and easy rate.

Although a small quantity only of distilled water can be obtained at a time by this confined operation, yet it compensates in strength what is deficient in quantity.

Such liquors, if well corked up from the air, will keep good a long time, especially if about a twentieth part of any spirits be added, in order to preserve the same more effectually.

Though British wines, &c. do not require the regular process of distillation, yet they are connected so materially with the other operations of the distiller as to demand our notice.

To make Gooseberry Wine.

Of gooseberries may be made a curious cooling wine, after the following directions:

Take gooseberries just beginning to turn ripe, not those that are quite ripe; bruise them as well as you did the grapes, but not so as to break their stones: then pour to every eight pounds of pulp a gallon of clear spring-water, or rather their own distilled water, made in a cold still, and let them stand in the vessel covered, in a cool place, twenty-four hours; then put them into a strong canvass or hair bag, and press out all the juice that will run from them, and to every quart of it put twelve ounces of loaf or other fine sugar, stirring it till it be thoroughly melted; then put it up into a well-seasoned cask, and set it in a cool place; when it has purged and settled about twenty or thirty days, fill the vessel full and bung it down close, that as little air as possible may come at it.

When it is well wrought and settled, then is your time to draw it off into smaller casks or bottles, keeping them in cool places, for there is nothing damages any sort of wines more than heat.

Another Method of Making Gooseberry Wine.

When the weather is dry, gather your gooseberries about the time they are half ripe; pick them clean, and put the quantity of a peck in a convenient vessel, and bruise them with a piece of wood, taking as much care as possible to keep the seeds whole. When you have done this, put the pulp into a canvass or hair bag, and press out all the juice; and to every gallon of the gooseberries add about three pounds of fine loaf sugar; mix it all together by stirring it with a stick, and as soon as the sugar is quite dissolved, pour it into a convenient cask, that will hold it exactly; and according to the quantity let it stand, viz. if about eight or nine gallons, it will take a fortnight; if twenty gallons, forty days, and so in proportion; taking care the place you set it in be cool. After standing the proper time, draw it off from the lees, and put it into another sweet vessel of equal size, or into the same, after pouring the lees out, and making it clean; let a cask of ten or twelve gallons stand about three months, and twenty gallons five months, after which it will be fit for bottling off.

This is a curious cooling drink, taken with great success in all hot diseases, as fevers, small-pox, the hot fit of the ague; it stops laxation, is good in the bloody-flux, cools the heat of the liver and stomach, stops bleeding, and mitigates inflammations; it wonderfully abates flushings and redness of the face, after hard drinking, or the like; provokes urine, and is good against the stone; but those that are of a very phlegmatic constitution should not make use of it.

To make Currant Wine.

Take four gallons of curious cooling spring or conduit water, let it gently simmer over a moderate fire, scum it well, and stir into it eight pounds of the best virgin honey; when that is thoroughly dissolved, take off the water, and stir it well about, to raise the scum, which take clean off, and cool.

When it is thus prepared, press out the like quantity of juice of red currants moderately ripe, without any green ones among them, which

being well strained, mix it well with the water and honey, then put them up in a cask, or large earthen vessel, and let them stand upon the ferment twenty-four hours; then to every gallon add two pounds of loaf or other fine sugar, stir them well to raise the scum, and, when well settled, take it off, and add half an ounce of cream of tartar, with a little fine flour, and the whites of two or three eggs, which will refine it; and when it is well settled and clear, draw it off into a small vessel, or bottle it up, keeping it in a cool place.

Of white currants, a wine after the same manner may be made that will equal in strength and pleasantness many sorts of white wine; but as for the black, or Dutch currants, I approve not of them but in medicinal wines, of which I shall have some occasion to speak hereafter.

Another way of Making Currant Wine.

After gathering your currants, which you must do when the weather is dry, and they are full ripe, strip them carefully from the stalk, so as not to bruise them with your fingers; put them into a pan, and bruise them with a convenient wooden pestle; then let it stand about twenty hours (according to the quantity) after which strain it through a sieve. Add three pounds of fine powder sugar to every four quarts of the liquor, and then shaking or stirring it well, fill your vessel, and put about a quart of good brandy to every six or seven gallons. As soon as it is fine, which will be in four or five weeks, you must bottle it off. If it should not prove quite clear, draw it off into another vessel, and let it stand about ten days, and then bottle it off.

To make excellent Punch.

One tea-spoonful of Coxwell's acid salt of lemons, a quarter of a pound of sugar, a quart of water nearly boiling, half a pint of rum, and a quarter of a pint of brandy; a little lemon peel may be added, or in place thereof, a few drops of essence of lemon.

To make a pleasant, sober, and refreshing Drink for the Summer.

Take one bottle of sherry (but Maderia is preferable), two bottles of cyder, one of perry, and one gill of brandy; and after those ingredients are mixed, take two lemons, pare the rind as thin as possible; then slice the lemons, and put the rind and lemons into a cup; to these add a little grated nutmeg and powdered sugar, to make it palatable; stir them together; then toast a biscuit very brown, and throw it hot into the liquor. It is generally found a pleasant draught at dinner, and produces no bad effects on those who drink it in moderation.

To make the German Liquor, Mum.

Mum is made of various sorts of grain, in the following proportions: to seven bushels of wheaten malt, add one bushel of oatmeal, one bushel of ground beans, and a variety of other articles, as the tops of fir, wild thyme, &c. also ten new laid eggs. These articles ought to be infused in sixty-three gallons of water boiled down to forty-one.

To make the celebrated Eastern Beverage called Sherbet.

This liquor is a species of negus without the wine. It consists of water, lemon or orange juice, and sugar, in which are dissolved perfumed cakes, made of the best Damascus fruit, and containing also an infusion

of some drops of rose-water: another kind is made of violets, honey, juice of raisins, &c. It is well calculated for assuaging thirst, as the acidity is agreeably blended with sweetness. It resembles, indeed, those fruits which we find so grateful when one is thirsty.

To make Birch-tree Wine.

The vernal sap of the birch-tree is made into wine. In the beginning of March, while the sap is rising, holes must be bored in the body of the tree, and fassets, made of elder, placed in them, to convey away the liquid. If the tree be large it may be tapped in several places at a time, and thus, according to the number of trees, the quantity of liquid is obtained. The sap is to be boiled with sugar, in the proportion of four pounds to a gallon, and treated in the same manner as other made wines.

One great advantage attaching to the birch is, that it will grow on almost any barren ground.

Another Mode for Currant Wine.

Gather your currants on a fine dry day, when the fruit is full ripe, steep them, put them in a large pan, and bruise them with a wooden pestle; let them stand in a pan or tub twenty-four hours to ferment, then run it through a hair sieve, and do not let your hand touch the liquor; to every gallon of this liquor put two pounds and a half of white sugar, stir it well together, and put it into your vessel. To every six gallons put in a quart of brandy, and let it stand six weeks; if it is fine, bottle it; if it is not, draw it off as clear as you can into another vessel, or large bottles, and in a fortnight bottle it into smaller bottles.

Elder Wine.

Pick the elder-berries when full ripe; put them into a stone jar, and set them in the oven, or a kettle of boiling water, till the jar is hot through; then take them out and strain them through a coarse cloth, wringing the berries, and put the juices into a clean kettle; to every quart of juice put a pound of fine Lisbon sugar; let it boil, and skim it well; when it is clear and fine, pour it into a jar; when cold, cover it close, and keep it till you make raisin wine; and to every gallon of wine put half a pint of elder syrup.

Grape Wine.

To every gallon of ripe grapes put a gallon of soft water, bruise the grapes, let them stand a week without stirring, and draw the liquor off fine; to every gallon of wine put three pounds of lump sugar; put it into a vessel, but do not stop it till it has done hissing, then stop it close, and in six months it will be fit to bottle.

A better wine, though smaller in quantity, will be made by leaving out the water, and diminishing the quantity of sugar. Water is only necessary where the juice is so scanty or so thick, as in cowslip, balm, or black currant wine, that it could not be used without it. Very good wine, after keeping for twelve months, has been made by adding a proper quantity of sugar to grapes which were so hard that it was necessary to burst them over the fire to get out the juice.

An Excellent Family Wine.

May be made of equal parts of red, white, and black currants, ripe cherries, and raspberries, well bruised, and mixed with soft water, in the proportion of four pounds of fruit to one gallon of water. When strained and pressed, three pounds of moist sugar are to be added to each gallon of liquid. After standing open three days, during which it is to be stirred frequently, and scum it as it may require, it is to be put into a barrel, and left for a fortnight to work, when a ninth part of brandy is to be added, and the whole bunged down; and in two or three years it will be rich and valuable.

To extract Syrup from Indian Corn.

The young spikes, when they are beginning to form, possess a very agreeable saccharine taste. Ten pounds of them squeezed in a stone mortar, and the juice expressed, after the leaves are stripped off, will give about four pounds of a milky juice, which, when clarified, and evaporated to the consistence of a syrup, will be found very agreeable to the palate. This vegetable will grow in England from the seed, sown in good soil.

Excellent Bitter for the Stomach.

One ounce of gentian root sliced, one ounce of fresh rind of lemon, two drachms of cardamom seeds bruised, three drachms of Seville orange peel; pour a pint and a half of boiling water over the ingredients, let it stand an hour, then decant the clear liquor, and take a wine glass full two or three times a day.

It should be kept closely covered after the water is put in the ingredients.

To detect Sugar of Lead in Wines.

The tincture of orpiment converts wine so adulterated to a black colour.

A Test for discovering in Wine, Metals that are injurious to the Health.

The property of liver of sulphur, and of hepatic gas, in precipitating lead of a black colour, has been long known; and that property has been made use of to ascertain the goodness of wine, in the preparation of the liquor *probatorius Wurtembergiensis.*

But in trying wines which we suspect to be adulterated, that proof does more harm than good; because it precipitates the iron of the same colour with the pernicious lead; by which means, some dealers of respectable characters have been ruined.

It was wanting, therefore, to find an agent which would discover nothing in wine but what was prejudicial to health. This is accomplished by the following test, which precipitates lead and copper of a black colour, arsenic of an orange colour, but does not iron, which being innocent, or rather salutary, to the human constitution, gets into a great number of different sorts of wine by various accidents.

Receipt for the test liquor.—Mix equal parts of oyster shells, and crude sulphur reduced to a fine powder, and put the mixture in a crucible. Heat this in a wind furnace, and suddenly raise the heat till the cruci-

ble is exposed to a white heat for fifteen minutes. When the mass is cool, reduce it to powder, and keep it in a bottle well corked.

To make the liquor, put 120 grains of this powder and 180 grains of cream of tartar into a strong bottle full of common water, which has been boiled for an hour, and suffered to cool. Cork the bottle immediately, and shake it from time to time. After having stood a few hours, pour off what is clear of the liquor into ounce phials, after having previously put into each of them twenty drops of spirit of sea salt; and then stop them well with wax mixed with a little turpentine.

One part of this liquor, mixed with three parts of wine adulterated, will discover, by a very sensible black precipitate, the smallest quantity of lead, copper, &c. but will have no effect on any iron it may contain. When the precipitation is made, iron may be discovered by saturating the wine remaining, when poured off, with a little salt of tartar, when the liquor becomes instantly black.

Pure wines remain perfectly clear after the addition of this liquor.

To make Raisin Wine.

To two hundred weight of raisins put about forty-four gallons of water, wine measure, stir it up well, three or four times a day; let it stand about three weeks, then take it off the raisins, and tun it up; when you put it into the cask, add about two quarts of brandy to it, which will keep it from fretting.

Let it stand about ten or twelve months, then draw it off from the lees; rince your cask, and put it in again; then fine it down with three ounces of isinglass, and a quarter of a pound of sugar-candy, dissolved in some of the wine. There are many ways used to retrieve this wine, if it should chance to turn sour, which seldom happens if properly made; in this case, the most successful method is to replenish it with a further addition of raisins.

Another Method of making Raisin Wine.

Put two hundred weight of raisins, with the stalks, into a hogshead, and fill it almost with spring water; let it steep about twelve days, frequently stirring them about, and after pouring the juice off, dress the raisins. The liquor should then be put together in a very clean vessel that will exactly contain it. You will find it hiss or sing for some time, during which it should not be stirred; but, when the noise ceases, it must be stopped close, and stand for about six or seven months; and then, if you peg it, and it proves fine and clear, rack it off into another vessel of the same size; stop it up, and let it remain twelve or fourteen weeks longer; then bottle it off. The best way, when you use it, is to take a decanter and rack it off.

To make Wines of Blackberries, Strawberries, or Dewberries.

Take of these berries, in their proper season, moderately ripe, what quantity you please; press them as other berries; boil up water and honey, or water and fine sugar, as your palate best relishes, to a considerable sweetness; and when it is well scummed, put the juice in and let it simmer to incorporate it well with the water; and when it is done so, take it off, let it cool, scum it again, and put it up in a barrel, or rather a close-glazed earthen vessel, to ferment and settle; to every gallon put

half a pint of Malaga, draw it off as clear as possible; bottle it up, and keep it cool for use.

To make Wine of Apples and Pears.

As for apples, make them first into good cider, by beating and pressing, and other orderings, as I shall direct, when I come to treat of those sort of liquors, after I have ended this of wines; and to good cider, when you have procured it, put the herb scurlea, the quintessence of wine, and a little fixed nitre, and to a barrel of this cider a pound of the syrup of honey; let it work and ferment at spurge-holes in the cask ten days, or till you find it clear and well settled, then draw it off, and it will not be much inferior to Rhenish in clearness, colour, and taste.

To make wine of pears, procure the tartest perry, but by no means that which is tart by souring, or given that way, but such as is naturally so; put into a barrel about five ounces of the juice of the herb clary, and the quintessence of wine, and to every barrel a pound, or pint of the syrup of blackberries, and, after fermentation and refining, it will be of a curious wine taste, like sherry, and not well distinguishable but by such as have very good palates, or those who deal in it.

To make Wine of Cherries.

Take cherries, indifferently ripe, of any red sort, clear them of the stalks and stones, and then put them into an earthen glazed pan vessel, and with your clean hands squeeze them to a pulp; or you may do it with a wooden ladle, or presser, and so let them continue twelve hours to ferment; then put them into a linen cloth, not too fine, and press out the juice with a pressing-board, or any other conveniency; then let the liquor stand till the scum arise, and with your ladle take it clean off; then pour out the clearer part, by inclination, into a cask, where to each gallon put a pound of the best loaf-sugar, and let it ferment and purge seven or eight days; draw it off, when you find it clear, into lesser casks, or bottles; keep it cool, as other wines, and in ten or twelve days it will be ripe.

To make Wine of Peaches and Apricots.

Take peaches, nectarines, &c. when they are full of juice, pare them, and take the stones out, then slice them thin, and put about a gallon to two gallons of water, and a quart of white wine; put them over a fire gently to simmer a considerable time, till the sliced fruit become soft; then pour off the liquid part into other peaches that have been so used and bruised, but not heated; let them stand twelve hours, sometimes with stirring, and then pour out the liquid part, and press what remains through a fine hair bag, and put them together into a cask to ferment; then add of loaf-sugar a pound and a half to each gallon; boil well an ounce of beaten cloves in a quart of white wine, and add it, which will give a curious flavour.

Wine of apricots may be made with only bruising and pouring the hot liquor on, not requiring so much sweetening, by reason they are of a more dulcet or luscious quality; only, to give it a curious flavour, boil an ounce of mace, and half an ounce of nutmegs, in a quart of white wine; and when the wine is on the ferment, pour the liquid part in hot, and hang a bunch of fresh borage, well flowered, into the cask, by a

string at the bung, for three days; draw it off, and keep it in bottles, which are most proper to preserve these sorts of wines.

To make Wine of Quinces.

Gather the quinces when pretty ripe, in a dry day, rub off the down with a clean linen cloth, then lay them in hay or straw for ten days, to sweat; so cut them in quarters, and take out the core, and bruise them well in a mashing tub with a wooden beetle, and squeeze out the liquid part, by pressing them in a hair bag by degrees in a cider press; strain this liquor through a fine sieve, then warm it gently over a fire, and scum it, but suffer it not to boil; sprinkle into it loaf sugar reduced to powder, then in a gallon of water and a quart of white wine, boil a dozen or fourteen large quinces thinly sliced; add two pounds of fine sugar, and then strain out the liquid part, and mingle it with the natural juice of the quinces; put it into a cask, not to fill it, and jumble them well together; then let it stand to settle: put in juice of clary half a pint to five or six gallons, and mix it with a little flour and whites of eggs, then draw it off, and, if it be not sweet enough, add more sugar, and a quart of the best malmsey; you may, to make it the better, boil a quarter of a pound of stoned raisins of the sun, and a quarter of an ounce of cinnamon, in a quart of the liquor, to the consumption of a third part, and straining the liquor, put it into the cask when the wine is upon the ferment.

To make Birch Wine.

As this is a liquor but little understood, I shall be as particular as possible in my directions concerning it. In the first place, as to tho season for getting the liquor from birch trees, which sometimes happens the latter end of February or beginning of March, before the leaves shoot out, as the sap begins to rise; and this is according to the mildness or rigour of the weather; and if the time is delayed, the juice will grow too thick to be drawn out, which should be as thin and clear as possible. The method of procuring the juice is by boring holes in the trunk of the tree, and fixing faucets made of elder; but care should be taken not to tap it in too many places at once, for fear of hurting the tree. If the tree is large, it may be bored in five or six places at once, and place bottles to let it drop in. When you have extracted a proper quantity, three, four, or five gallons, from different trees, cork the bottles very close, and rosin or wax them till you begin to make your wine, which should be as soon as possible after you have got the juice.

As soon as you begin, boil the sap as long as you can take off any scum; and put four pounds of fine loaf sugar to every gallon of the juice, and the peel of a lemon cut thin; then boil it again for near an hour, scumming it all the while, and pour it into a tub. As soon as it is almost cold, work it with a toast spread with yeast, and let it stand five or six days, stirring it twice or three times each day. Take a cask that will contain it, and put a lighted match dipped well in brimstone into the cask; stop it up till the match is burnt out, and then tun your wine into it, putting the bung lightly in till it has done working. Bung it very close for about three months, and bottle it off for use. It will be fit in a week after it is put in the bottles.

To make Wine of Plums, Damsons, &c.

To do this, take what plums you please, mix those of a sweet taste with an allay of those that are somewhat sour, though they must be all inclining to ripeness; slit them in halves, so that the stones may be taken out, then mash them gently, and add a little water and honey; the better to moisten them, boil to every gallon of pulp of your plums a gallon of spring water, in it a few bay leaves and cloves; add as much sugar as will well sweeten it, scum off the froth, and let it cool, then press the fruit, squeezing out the liquid part; strain all through a fine strainer, and put the water and juice up together in a cask; let it stand and ferment three or four days, fine it with white sugar, flour, and whites of eggs, draw it off into bottles, then cork it up, that the air may not prejudice it; in twelve days it will be ripe, and taste like sherry, or rather a nearer flavour of canary.

Damsons may be ordered as other plums, though they produce a tarter wine, more clear and lasting; but put not so much water to them as to luscious plums, unless you mix some sweet wine with it, as Malaga, Canary, or the like; or infuse raisins of the sun in it, which will give it a rich and mellow taste.

To make Wine of English Figs.

To do this, take the large blue figs, pretty ripe; steep them in white wine, having made some slits in them, that they may swell, and gather in the substance of the wine, then slice some other figs, and let them simmer over a fire in fair water till they are reduced to a kind of pulp, strain out the water, pressing the pulp hard, and pour it as hot as may be to those figs that are imbued in the wine; let the quantities be nearly equal, the water somewhat more than the wine and figs; then, having infused twenty-four hours, mash them well together, and draw off what will run voluntarily, then press the rest, and if it prove not pretty sweet, add loaf sugar to render it so: let it ferment, and add a little honey and sugarcandy to it, then fine it with whites of eggs and a little isinglass, and so draw it off, and keep it for use.

To make Wine of Roses.

To do this, fit a glass basin, or body, or for want of it, a well glazed earthen vessel, and put into it three gallons of rose water, drawn with a cold still; put into it a convenient quantity of rose leaves; cover it close, and put it for an hour in a kettle or cauldron of water, heating it over the fire to take out the whole strength and tincture of the roses, and when cold, press the rose leaves hard into the liquor, and steep fresh ones in, repeating it till the liquor has got a full strength of the roses; and then to every gallon of liquor add three pounds of loaf sugar; stir it well, that it may melt and disperse in every part; then put it up into a cask, or other convenient vessel to ferment; and to make it do so the better, add a little fixed nitre and flour, and two or three whites of eggs; let it stand to cool about thirty days, and it will be ripe, and have a curious flavour, having the whole strength and scent of the roses in it; and you may add, to meliorate it, some wine and spices, as your taste or inclination leads you.

By this way of infusion, wine of carnations, clove gilliflowers, vio-

lets, primroses, or any flower having a curious scent, may be made; to which, to prevent repetition, I refer you.

To make Wine of Raspberries the English way.

Take what quantity you please of red raspberries, when they are nearly ripe, for if they grow over ripe they will lose much of their pleasant scent; and after clearing the husks and stalks from them, soak them in the like quantity of fair water, that has been boiled and sweetened with fine loaf sugar, a pound and a half to a gallon; when they are well soaked about twelve hours, take them out, put them into a fine linen pressing bag, press out the juice into the water, then boil them up together, and scum them well twice or thrice over a gentle fire; take off the vessel, and let the liquor cool, and when the scum arises take off all that you can, and pour off the liquor by inclination into a well seasoned cask, or earthen vessel; then boil an ounce of mace quite down, if possible, in a pint of white wine, till the third part of the wine be consumed; strain it, and add it to the liquor: let it settle two days, and when it has well settled and fermented, draw it off into a cask, or bottles, and keep it in a cool place.

The French way of making this Wine.

Steep two gallons of raspberries in a gallon of sack twenty-four hours, then strain them, and put to the liquor three quarters of a pound of raisins of the sun, well stoned, and let them continue four or five days, sometimes stirring them well; then pour it off gently, that the clearest may be taken away, and only the dregs and settlings remain, and bottle that up you pour off. If you find it not sweet enough for the palate, you may add some sugar, about half a pound to a gallon will be sufficient; keep it in a cool place.

Another Way to make Raspberry Wine.

Gather the raspberries when ripe, and bruise them; strain them through a bag made of woollen into a jar. Put about a pound of the best double refined loaf sugar; mix the whole well together, and stop it close. Pour it off as clear as possible, after it has stood four days. The common method is to put two quarts of white wine to one quart of the raspberry juice; but I think that too much, as it overpowers the rich flavour of the fruit; three pints will be enough. Bottle it off, and it will be fit to drink in ten days. The juice mixed with brandy, is a fine dram. Put about two quarts of brandy to three quarts of raspberry juice, and it will drink well in ten days.

To make Wine of Mulberries.

Take mulberries, when they are just changed from their redness to a shining black, gather them in a dry day, when the sun has taken off the dew, spread them thinly on a fine cloth, on a floor or table, for twenty-four hours, boil up a gallon of water to each gallon of juice you get out of them; scum the water well, and add a little cinnamon slightly bruised; put to every gallon six ounces of white sugar-candy, finely beaten, scum and strain the water when it is taken off and settled, and put to it the juice of mulberries, and to every gallon the mixture of a pint of white or rhenish wine; let them stand in a

cask to purge or settle five or six days, then draw off the wine, and keep it cool.

To make Morella Wine.

Take two gallons of white wine, and twenty pounds of Morella cherries; take away the stalks, and so bruise them that the stones may be broken: press the juice into the wine; put mace, cinnamon, and nutmeg, each an ounce, in a bag grossly bruised, hang it in the wine when you have put it up in a cask, and it will be a rich drink.

To make Vinum Sambuceum, or Elderberry Wine.

Take elderberries, when pretty ripe, plucked from the green stalks, what quantity you please, and press them that the juice may freely run from them, which may be done in a cider-press, or between two weighty planks, or, for want of this opportunity, you may mash them, and then it will run easily; this juice put up in a well seasoned cask, and to every barrel put three gallons of water strong of honey boiled in it, and add some ale yeast to make it ferment, and work out the grossness of its body; then, to clarify it, add flour, whites of eggs, and a little fixed nitre; and when it has well fermented, and grows fine, draw it from the settlings, and keep it till spring; then to every barrel add five pounds of its own flowers, and as much loaf sugar, and let it stand seven days; at the end whereof it will grow very rich, and have a good flavour.

A different Way to make Elder Wine.

When the elderberries are ripe, pick them, and put them into a stone jar; then set them in boiling water, or rather in an oven not over hot, till the jar is as warm as you can well bear to touch it with your hand; take the berries and strain them through a sieve or coarse cloth, squeezing them hard, and pour the liquor into a kettle. Put it on the fire, let it boil, and put in as many pounds of Lisbon sugar as there are quarts of juice, and scum it often; then let it settle, and pour it off into a jar, and cover it close. I have known many people mix it with their raisin wine, by putting half a pint of the elder syrup to every gallon of wine; it gives the raisin wine an exquisite fine flavour, equal to any foreign wine whatever.

To make Elder Flower Wine.

To six gallons of spring water put six pounds of raisins of the sun, cut small, and a dozen pounds of fine powder sugar; boil the whole together about an hour and a half; then take elder flowers, when pretty ripe, and pull them off to about half a peck. When the liquor is cold, put the flowers in, and about a gill of lemon juice, and half the quantity of ale yeast. Cover it up, and, after standing three days, strain it off, pour it into a cask that is quite sweet, and that will hold it with ease. When this is done, put about a wine quart of Rhenish to every gallon of wine, let the bung be lightly put in for twelve or fourteen days; then stop it down fast, and put it in a cool dry place for four or five months, till it is quite settled and fine; and bottle it off.

To make Cowslip Wine.

Put five pounds of loaf sugar to four gallons of fair water, simmer them over a fire half an hour, to well dissolve the sugar, and when it is taken off, and cold, put in half a peck of cowslip flowers, clean picked and gently bruised; then put two spoonsful of new ale yeast, and a pound of syrup of lemons beaten with it, with a lemon peel or two. Pour the whole into a well seasoned cask or vessel, let them stand close stopped for three days, that they may ferment well; then put in some juice of cowslips, and give it a convenient space to work, and when it has stood a month draw it off into bottles, putting a little lump of loaf sugar into each, by which means you may keep it well the space of a year. In like manner you may make wine of such other like flowers that are of a pleasant taste and scent, as oxlips, jessamine, peach blooms, comfry, scabeous, featherfew, fumitary, and many more, as your fancy and taste may lead you; having shewed you different ways to let you know that you need not exactly keep to one certain rule, but please your palate by such additions as you think convenient; though, by straying too far, you may happen to mar the whole design: therefore in all things, keep as near as you can to the rules I have given.

To make Scurvygrass Wine.

Scurvygrass, or spoonwort, is a very sovereign medicinal herb, appropriated chiefly to the health of English bodies.

Take the best large scurvygrass tops and leaves, in May, June, or July, bruise them well in a stone mortar, then put them in a well glazed earthen vessel, and sprinkle them over with some powder of chrystal of tartar, then smear them over with virgin honey, and being covered close, let it stand twenty-four hours; then set water over a gentle fire, putting to every gallon three pints of honey, and when the scum rises, take it off, and let it cool; then put your stamped scurvygrass into a barrel, and pour the liquor to it, setting the vessel conveniently end-ways, with a tap at the bottom, and when it has been infused twenty-four hours, draw off the liquor, and strongly press the juice and moisture out of the herb into the barrel or vessel, and put the liquor up again; then put a little new ale yeast to it, and suffer it to ferment three days, covering the place of the bung or vent with a piece of bread spread over with mustard seed, downward, in a cool place, and let it continue till it is fine and drinks brisk; then is the time to draw off the finest part, leaving only the dregs behind: add more herbs, and ferment it with whites of eggs, flour, and fixed nitre, ver juice, or the juice of green grapes, if they are to be had; to which add six pounds of the syrup of mustard, all mixed and well beaten together, to refine it down, and it will drink brisk, but is not very pleasant; being here inserted among artificial wines rather for the sake of health than for the delightfulness of its taste.

To make Wine of Mint, Balm, and other Herbs, &c.

First, distil the herb in the cold still, then add honey to it, and work as in scurvygrass, and then refine it, and work it down by a due proportion of its own syrup; by this means the wine will become very fragrant, and contain the whole virtue of the herb: wormwood wine, wine of rue, cardus, and such strong physical herbs, may be made by in-

fusion only, in small white wines, cider, perry, or the like, adding a little sweets to palate them, that they may be more agreeable to the taste. That of black currants may be made as of other currants, and is very useful in all families.

To make Orange Wine.

Put twelve pounds of fine sugar, and the whites of eight eggs, well beaten, into six gallons of spring water; let it boil an hour, scumming it all the time; take it off, and when it is pretty cool, put in the juice of fifty Seville oranges, and six spoonsful of good ale yeast, and let it stand two days: then put it in another vessel with two quarts of Rhenish wine and the juice of twelve lemons; you must let the juice of lemons and wine, and two pounds of double refined sugar, stand close covered ten or twelve hours before you put it into the vessel to your orange wine, and scum off the seeds before you put it in. The lemon-peels must be put in with the oranges, half the rinds must be put into the vessel: it must stand ten or twelve days before it is fit to bottle.

To make Sage Wine.

Boil twenty-six quarts of spring water a quarter of an hour, and, when it is blood warm, put twenty-five pounds of Malaga raisins, picked, rubbed, and shred, into it, with almost half a bushel of red sage shred, and a porringer of ale yeast; stir all well together, and let it stand in a tub, covered warm, six or seven days, stirring it once a day; then strain it off, and put it in a runlet. Let it work three or four days, and then stop it up; when it has stood six or seven days, put in a quart or two of Malaga sack; and when it is fine bottle it.

To make Turnip Wine.

Take a good many turnips, pare them, slice them, put them into a cider press, and press out all the juice very well. To every gallon of juice have three pounds of lump sugar; have a vessel ready just big enough to hold the juice; put your sugar into a vessel; and also to every gallon of juice half a pint of brandy. Pour in the juice, and lay something over the bung for a week, to see if it works; if it does, you must not bring it down till it has done working; then stop it close for three months, and draw it off into another vessel. When it is fine bottle it off.

Cyprus Wine imitated.

You must to nine gallons of water put nine quarts of the juice of the white elderberries, which has been pressed gently from the berries with the hand, and passed through a sieve, without bruising the kernels of the berries: add to every gallon of liquor three pounds of Lisbon sugar, and to the whole quantity put an ounce and a half of ginger sliced, and three quarters of an ounce of cloves; then boil this near an hour, taking off the scum as it rises, and pour the whole to cool in an open tub, and work it with ale yeast spread upon a toast of white bread, for three days, and then turn it into a vessel that will just hold it, adding about a pound and a half of raisins of the sun, split, to lie in liquor till we draw it off, which should not be till the wine is fine, which you will find in January.

This wine is so much like the fine rich wine brought from Cyprus, in its colour and flavour, that it has deceived the best judges.

To make Gilliflower Wine.

To three gallons of water put six pounds of the best powder sugar, boil the sugar and water together for the space of half an hour, keep scumming it as the scum rises; let it stand to cool, beat up three ounces of syrup of betony with a large spoonful of ale yeast, put it into the liquor, and brew it well together; then having a peck of gilliflowers, cut from the stalks, put them into the liquor, let them infuse and work together three days, covered with a cloth; strain it, and put it into a cask, and let it settle for three or four weeks, then bottle it.

To make Mead.

Having got thirteen gallons of water, put thirty pounds of honey to it, boil and scum it well; then take rosemary, thyme, bay leaves, and sweetbriar, one handful altogether; boil it an hour; then put it into a tub, with two or three handfuls of ground malt; stir it till it is blood warm; then strain it through a cloth, and put it into a tub again; cut a toast round a quartern loaf, and spread it over with good ale yeast, and put it into your tub; and when the liquor is quite over with the yeast, put it up in your vessel; then take of cloves, mace, and nutmegs, an ounce and a half; of ginger sliced, an ounce; bruise the spice, and tie it up in a rag, and hang it in the vessel; stop it up close for use.

General Rules for the Distillation of Simple Waters.

1. Plants and their parts ought to be fresh gathered. Where they are directed fresh, such only must be employed; but some are allowed to be used dry, as being easily procurable in this state at all times of the year, though rather more elegant waters might be obtained from them whilst green.

2. Having bruised the subjects a little, pour thereon thrice its quantity of spring water.

This quantity is to be diminished or increased, according as the plants are more or less juicy than ordinary.

When fresh and juicy herbs are to be distilled, thrice their weight of water will be fully sufficient, but dry ones require a much larger quantity.

In general, there should be so much water, that after all intended to be distilled has come over, there may be liquor enough left to prevent the matter from burning to the still.

3. Formerly some vegetables were slightly fermented with the addition of yeast, previous to the distillation.

4. If any drops of oil swim on the surface of the water, they are carefully taken off.

5. That the waters may be kept the better, about one-twentieth part of their weight of proof spirit may be added to each, after they are distilled.

Stills used for Simple Waters.

The instruments chiefly used in the distillation of simple waters are of two kinds, commonly called the hot still, or alembic, and the cold still

The waters drawn by the cold still from plants are much more fragrant, and more fully impregnated with their virtues, than those drawn by the hot still, or alembic. The method is this:

A pewter body is suspended in the body of the alembic, and the head of the still fitted to the pewter body; into this body the ingredients to be distilled are put, the alembic filled with water, the stillhead luted to the pewter body, and the nose luted to the worm of the refrigeratory or worm.

The same intention will be answered, by putting the ingredients into a glass alembic, and placing it in a bath heat, or balneum mariæ.

The cold still is much the best adapted to draw off the virtues of simples, which are valued for their fine flavour when green, which is subject to be lost in drying; for when we want to extract from plants a spirit so light and volatile as not to subsist in open air any longer than while the plant continues in its growth, it is certainly the best method to remove the plant from its native soil, into some proper instrument, where, as it dies, these volatile parts can be collected and preserved. And such an instrument is what we call the cold still, where the drying of the plant, or flower, is only forwarded by a moderate warmth, and all that rises is collected and preserved.

As the method of performing the operation by the cold still is the very same, whatever plant or flower is used, the following instance of procuring a water from rosemary, will be abundantly sufficient to instruct the young practitioner in the manner of conducting the process in all cases whatever.

Take rosemary, fresh gathered in its perfection, with the morning dew upon it; and lay it lightly and unbruised upon the plate or bottom of the still; cover the plate with its conical head, and apply a glass receiver to the nose of it. Make a small fire of charcoal under the plate, continuing it as long as any liquor comes over into the receiver.

When nothing more comes over, take off the still head, and remove the plant, putting fresh in its stead, and proceed as before; continue to repeat the operation successively, till a sufficient quantity of water is procured

Let this distilled water be kept at rest in clean bottles, close stopped, for some days in a cold place; by this means it will become limpid, and powerfully impregnated with the taste and smell of the plant.

In this water are contained the liquor of dew, consisting of its own proper parts, which are not without difficulty separated from the plant, and cleave to it even in drying. This dew also, by sticking to the outside, receives the liquid parts of the plant, which being elaborated the day before, and exhaled in the night, are hereby detained, so that they concrete together into one external liquid, which is often viscid, as appears in manna, honey, &c.

Simple Alexeterial Waters.

Take of spearmint leaves, fresh, a pound and a half; sea wormwood tops, fresh, angelica leaves, fresh, each one pound; water, as much as is sufficient to prevent burning. Draw off by distillation three gallons.

Or, Take of elder flowers, moderately dried, two pounds; angelica leaves, fresh gathered, one pound; water, a sufficient quantity. Distil off three gallons.

These waters are sufficiently elegant with regard to taste and smell, though few expect from them such virtues as their title seems to imply.

Simple Cinnamon Water.

Take of cinnamon, one pound; water, a gallon and a half; steep them together for two days; and then distil off the water till it ceases to run milky.

This is a very grateful and useful water, possessing in an eminent degree the fragrance and aromatic virtues of the spice.

Simple Peppermint Water.

Take of peppermint leaves, dry, a pound and a half; water, as much as will prevent the leaves burning.

Draw off by distillation one gallon.

This is a very elegant and useful water. It has a warm pungent taste, exactly resembling that of the peppermint itself.

Simple Pennyroyal Water.

Take of pennyroyal leaves, dry, a pound and a half; water, as much as will prevent burning.

Draw off by distillation one gallon.

Water of Pennyroyal.

Take of pennyroyal leaves, fresh, any quantity; water, three times as much. Distil as long as the water comes off well flavoured of the herb.

These waters possess, in a considerable degree, the smell, taste, and virtues of pennyroyal.

They are frequently taken in hysteric cases, and not without good effects.

This water is principally valued on account of its fine flavour, which approaches to that generally admired in the rose itself.

Damask Rose Water.

Take of damask roses, fresh gathered, six pounds; water as much as will keep them from burning. Distil off a gallon of the water.

Or, Take three parts of water to one of the fresh roses, and distil as long as the water which comes over has smell of the flowers.

This water is principally valued on account of its fine flavour, which approaches to that generally in the rose itself. The purgative virtue of the roses remain entire in the liquor left in the still, which has therefore been generally employed for making the solutive honey, and syrup, instead of decoction or infusion of fresh roses prepared on purpose: and this piece of frugality the college have now admitted.

Receipt for Orange Flower Water.

Take two pounas of orange flowers, and twenty-four quarts of water, and draw over three pints.

Or, Take twelve pounds of orange flowers, and sixteen puarts of water, and draw over fifteen quarts.

Receipt for one gallon of Orange Peel Water.

The orange is a fruit too well known to need any comment.

Take of the outward yellow rind of Seville oranges, four ounces; water, three gallons and a half; draw off one gallon by the alembic, with a pretty brisk fire.

Simple Spearmint Water.

Take of spearmint leaves, fresh, any quantity; water, three times as much. Distil as long as the liquor which comes over has a considerable taste or smell of the mint.

Or, Take spearmint leaves, dried, a pound and a half; water, as much as is sufficient to prevent burning. Draw off by distillation one gallon.

These waters smell and taste very strong of the mint; and prove, in many cases, useful stomachics.

Boerhaave commends them (cohobated) as a present and incomparable remedy for strengthening a weak stomach, and curing vomiting proceeding from cold viscous phlegm, as also in lienteries.

To make up Rum, Brandy, and Hollands Gin.

On the arrival of the West India fleets, it is usual for dealers in spirits to purchase large quantities of rum from the importers at once, and acquaint their correspondents therewith, and the price they then bear; part of the rums are bonded, and the remainder taken home. Preparation being made for their reception, the above rums are carted home, and started into a back or a large vessel, the overproof reduced with water. Being well rummaged, and further reduced, suppose we say to one in ten under proof (which is a good mercantile strength). In purchasing rums you may have some from Barbadoes, Antigua, and other sugar plantations, as well as Jamaica; for it cannot be supposed that Jamaica can supply all the country with rums; therefore by mixing the different rums together, and letting them remain in the aforesaid back till they are wanted, will greatly mellow and improve their flavour.

Having given the process, it is necessary to demonstrate clearly what each puncheon stands you in.

Made up Rum.

Jamaica rum one hundred gallons, one to three and four per cent.
The per cents 37 reduced

		£	s.	d.
	137 gallons of proof spirits at 18s. per gallon,	£123	0	0
	17 further reduced to 1 in 10			
	154 gallons 1 in 10 under proof at 19s. per gallon	146	6	0
Bought at first cost		123	0	0
		£23	6	0

It appears by this calculation, there is a profit on each puncheon, twenty-three pounds, six shillings. From this sum, the various expenses and losses must be deducted, and the remainder will be the distiller's profit.

The above calculations will answer for brandy and Hollands geneva, and you can make them up to any strength, but not under one in six.

To make British Brandy.

To sixty gallons of clean rectified spirits, put one pound of sweet spirit of nitre into it, one pound of cassia buds ground, one pound of bitter almond meal (cassia and almond meal to be mixed together), before they are put to the spirits, two ounces of orris root, sliced (not powdered), and about thirty or forty prune stones, pounded; rummage them all well together two or three times a day, for three days or more; let them settle, then add one gallon of the best wine vinegar; and if you wish to have it better than British brandy is in common, add to every four gallons one gallon of foreign brandy, which will make it nearly equal to foreign itself.

To make an Artificial Proof.

To make an artificial proof for spirits, take pearl ashes, a quarter of a pound; pot ashes, ditto; soper's lye water, three quarts; one ounce of the oil of vitriol, one pint of the oil of almonds; lime water, one gallon; add a little of this mixture to your goods by degrees till you find it carries a good head.

Notwithstanding we have given this receipt, we do not recommend any person in the spirit trade to make use of it.

To make a Four Gallon Cask of Lime Water.

Take eight pounds of unslaked lime, put it into a pail or tub, and pour on it three quarts of water to dissolve it; in about an hour after add three gallons more of water, and let it stand for twenty-four hours; then pour the fine off into your four gallon cask, and put a cock in it, and it is always ready for use.

Some may think lime water is very unwholesome, but it is quite the contrary; it is much used in medicine, and the distillers wash their back with it.

Capillaire.

Take fourteen pounds of loaf sugar, three pounds of coarse sugar, and six eggs, well beat up. Put these into three quarts of water; boil it up twice, skim it well, and then add a quarter of a pint of orange flower water; strain it through a jelly bag, and put it into bottles for use. A spoonful or two of this syrup put into a draught of either warm or cold water, makes it drink exceeding pleasant.

The Vitriolic Liquor, or Ether.

Take of rectified spirit of wine, oil of vitriol, of each thirty-two ounces; pour the spirit into a glass retort, that will bear the sudden heat, and pour the acid, at once, upon it; mix them gradually and cautiously together, by gently shaking the retort; and immediately distil by a sand heat, prepared beforehand for that purpose, the recipient being placed in a vessel of snow or water. The fire should be so regulated,

that the liquor may boil as soon as possible, and continued to boil till sixteen ounces are distilled, when the retort is to be removed.

To the distilled liquor add two drachms of the stronger common caustic; and distil again, from a very high retort, with a very gentle fire, the recipient being placed as before in a refrigeratory. Continue the distillation till ten ounces are drawn off.

To the acid residuum, after the distillation, if you pour sixteen ounces of rectified spirit of wine, and repeat the distillation, more etherial liquor may be obtained; and this process may be repeated several times.

The preparation of this singular fluid has hitherto been confined to few hands; for though several processes have been published for obtaining it, the success of most of them is precarious, and some of them are accompanied with danger to the operator. Where the dulcified spirit only is the object, the method, as before directed for it, succeeds to perfection: but when it is made with a view to the other, a variation is necessary; for only a small quantity of ether can be separated from the spirit so prepared; there, the distillation is performed with an equable and gentle heat; here the fire should be hastily raised, so as to make the liquor boil; for on this circumstance the produce of ether principally depends.

Ether is the lightest, most volatile, and inflammable of all known liquids. It is lighter than the most highly rectified spirit of wine, in proportion of about seven to eight. A drop let fall on the hand, evaporates almost in an instant, scarcely rendering the part moist. It does not mix, but only in a small quantity, with water, spirit of wine, alkaline lixivia, volatile alkaline spirits, or acids; but is a powerful dissolvent for oils, balsams, resins, and other analogous substances. It has a fragrant odour, which, in consequence of the volatility of the fluid, is diffused through a large space. Its medical virtues are not as yet much known, though it is not to be doubted that a fluid of so much subtilty must have considerable effects. It has often been found to give ease in violent headachs, by being applied externally to the part, and to relieve the toothach by being laid on the afflicted jaw. It has been given also internally, with benefit, in hooping coughs and hysterical cases, from two or three drops to five and twenty, in a glass of wine or water, which should be swallowed as quick as possible, as the ether so speedily exhales.

Dulcified Spirit of Nitre.

Take of rectified spirit of wine, three pounds; nitrous acid, one pound; pour the rectified spirit of wine into a large bolt head, placed in a vessel of cold water, and add by degrees the acid, carefully shaking the vessel; set it in a cool place, lightly stopped, for seven days; afterwards distil the liquor in a water bath, the receiver being placed in a vessel filled either with water or snow, as long as any spirit arises.

Here the operator must take care not to invert the order of mixing the two liquors, by pouring the vinous spirit into the acid; for if he should, a violent effervescence and heat would ensue, and the matter be dispersed, in highly noxious red fumes. The most convenient and safe method of performing the mixture seems to be, to put the inflammable spirit into a large glass body, with a narrow mouth, placed under a chimney, and to pour upon it the acid, by means of a glass funnel, in very small quantities at a time, shaking the vessel as soon as the effer-

vescence ensuing upon each addition ceases, before a fresh quantity is put in. By these means the glass will be heated equally, and be prevented from breaking. During the action of the two spirits upon one another, the vessel should be lightly covered; if close stopped, it will burst; and, if left entirely open, some of the more valuable parts will exhale. Lemery directs the mixture to be made in an open vessel, by which unscientifical procedure he usually lost, as he himself observes, half his liquor: and we may presume that the remainder was not the medicine here intended.

Dulcified spirit of nitre has been long held, and not undeservedly, in great esteem. It quenches thirst, promotes the natural secretions, expels flatulencies, and moderately strengthens the stomach. It may be given from twenty drops to a drachm, in water, tea, or wine. Mixed with a small quantity of spirit of hartshorn, the spiritus volatilis aromaticus, or any other alkaline spirit, it proves a mild, yet efficacious, diaphoretic, and often notably diuretic; especially in some febrile cases, where such a salutary evacuation is wanted. A small proportion of this spirit, added to malt spirits, gives them a flavour approaching to that of French brandy.

Every Family to make their own Sweet Oil.

It is reported, a person is going to take out a patent for making a small hand-mill, for every family to make their own sweet oil. This may easily be done, by grinding or beating the seeds of white poppies into a paste, then boil it in water, and skim off the oil as it rises; one bushel of seed weighs fifty pounds, and produces two gallons of oil. Of the sweet olive oil sold, one-half is of oil of poppies. The poppies will grow in any garden: it is the large head white poppy, sold by apothecaries. Large fields are sown with poppies in France and Flanders, for the purpose of expressing oil from their seed for food. Vide 10th and 11th vols. of Bath Society papers, where a premium of twelve guineas is offered for the greatest number of acres sown in 1808 and 1809. When the seed is taken out, the poppy head when dried is boiled to an extract, which is sold at two shillings per quart.

To make Verjuice.

The acid of the juice of the crab or wilding is called by the country people verjuice, and is much used in recent sprains, and in other cases, as an astringent or repellent. With a proper addition of sugar, it is probable that a very grateful liquor might be made of this juice, but little inferior to old hock.

Method of making Vinegar.

To every gallon of water put a pound of coarse Lisbon sugar; let the mixture be boiled, and skimmed so long as any scum arises. Then let it be poured into proper vessels; and when it is as cool as beer when worked, let a warm toast, rubbed over with yeast, be put to it. Let it work about twenty-four hours, and then put it into an iron-hooped cask, and fixed either near a constant fire, or where the summer sun shines the greater part of the day; in this situation it should not be closely stopped up, but a tile, or something similar, laid on the bung hole, to keep out the dust and insects. At the end of about three months (sometimes less) it will be clear, and fit for use, and may be

bottled off. The longer it is kept after it is bottled the better it will be. If the vessel containing the liquor is to be exposed to the sun's heat, the best time to begin making it is in April.

To make Vinegar with the Refuse of Bee-hives, after the Honey is extracted.

When honey is extracted from the combs by means of pressure, take the whole mass, break and separate it, and into each tub or vessel put one part of combs and two of water: place them in the sun, if his rays possess a sufficient power, or in a warm place, and cover them with cloths. Fermentation takes place in a few days, and continues from eight to twelve days, according to the higher or lower temperature of the situation in which the operation is performed. During the fermentation, stir the matter from time to time, and press it down with the hands, that it may be perfectly soaked. When the fermentation is over, put the matter to drain upon sieves or strainers. At the bottom of the vessels will be found a yellow liquor, which must be thrown away, because it would soon contract a disagreeable smell, which it would communicate to the vinegar. Then wash the tubs, put into them the water separated from the other matter; it immediately begins to turn sour; when the tubs must be again covered with cloths, and kept moderately warm. A pellicle or skin is formed on their surface, beneath which the vinegar acquires strength; in a month's time it begins to be sharp; it must be left standing a little longer, and then put into a cask, of which the bung hole is left open, and it may then be used like any other vinegar.

To strengthen Vinegar.

Suffer it to be repeatedly frozen, and separate the upper cake of ice or water from it.

Balsamic and Anti-putrid Vinegar.

Acetic acid may be mixed with aromatics, as in Henry's thieves vinegar, in a quantity sufficient for a small smelling bottle, at no great expense. But it is the acetic acid which is useful, and not the aromatics, which are added for the pleasure of the perfume. Acetous acid or common vinegar, with or without aromatics, has little or no anti-putrid quality

Gooseberry Vinegar.

Take the gooseberries, when full ripe, stamp them small; to every quart put three quarts of water, stir them well together; let it stand twenty-four hours, then strain it through a canvas bag.

To every gallon of liquor add one pound of brown sugar, and stir them well together before you barrel your liquor.

The old bright yellow English gooseberries are the best.

To make Primrose Vinegar.

To fifteen quarts of water put six pounds of brown sugar; let it boil ten minutes, and take off the scum: pour on it half a peck of primroses; before it is quite cold put in a little fresh yeast, and let it work in a warm place all night; put it in a barrel in the kitchen, and when done working, close the barrel, still keeping it in a warm place.

Method of rendering putrid Water Sweet.

In a course of experiments which a gentleman was making, he had occasion to mix clay with a large quantity of water in a cistern.

After the water and clay had remained thus for some weeks, he tasted the water before it should be thrown out, and found it sweet and well flavoured. On this he stirred them, to find whether any putrid stench might rise from the bottom, but was agreeably surprised to find that the whole was equally sweet.

He now resolved to keep it longer, in order to determine what effect time might have on the mixture, and, if my memory serves me right, repeated the tastings and stirrings for several months, with equal success, though some part of the time was summer, during which he expected that the water would have become highly putrid.

He communicated this discovery to the society for the encouragement of arts, &c. it was referred to the committee of chemistry, with orders to make what experiments should seem to them requisite to determine a point so necessary to the welfare of numbers, as many diseases are known to take their rise from putrid water. The whole was confirmed by the report of the committee. Here is then a very easy means whereby every cottager has it in his power constantly to use sweet and wholesome water.

It is no more than mixing with water a quantity of common clay, sufficient to take off its transparency, so far as that the hands, held just under the surface, shall not appear through it.

Note.—This experiment has since been tried by mixing clay with putrid water in a close salt-glazed earthen vessel. The water did not become sweet. The experiment must not be made in a close vessel, for the effect of ventilation in sweetening putrid water is well known. Now water in a stone or lead cistern freely exposed to the air, and particularly if the growth of confervæ be prevented by excluding the light, will not become putrid in the greatest heat of this climate, unless it be mixed with a very uncommon proportion of some decomposeable animal or vegetable substance. The diffusing of clay in water may however have some effect upon it; for it has been observed, that horses prefer the water of a clay pit: and if there be any disengaged vitriolic acid in the clay, that acid may take off the putridity.

Perhaps charred casks preserve water longer than any other method.

To purify Water for domestic and other Purposes.

This method is extremely simple, and consists in placing horizontally, in the midst of a common water butt, a false bottom, perforated with a great number of small holes. The butt being thus divided into two equal parts, the upper is filled with pieces of charcoal, which must be neither too large nor too small, thoroughly burned, light, and well washed. Immediately under the cock, by which the water enters the butt, must be placed a small hollow cylinder, being merely to break the force of the water, and prevent it from falling upon the charcoal with such violence as to detach from it any particles of dirt, and wash them through into the lower receptacle; it is of little consequence of what material it is made. M. Siauve thinks that this contrivance might be made subservient to the interests of agriculture as well as domestic economy; and that it would be highly advantageous to provide water thus

filtered for the cattle, during the whole of the dog-days, and particularly when the ponds and streams are infected by the rotting of hemp and flax.

Remark.—A very good filtre may be made of charcoal, but it is comparatively expensive; and there is a patent for the only way in which the filtre can be made to last. In the above receipt, if the charcoal is not in very fine powder, it will have little effect in purifying the water; if it be, the charcoal will very soon choke from the quantity of mud deposited in it by the water, and the frequent renewals of the charcoal, which would be necessary from the choking, would be found expensive. The contrivance could only be useful as a temporary means of ascertaining the power of the charcoal on the particular kind of water, with a view afterwards to procure a proper filtre.

To purify Water for Drinking.

Filtre river water through a sponge, more or less compressed, instead of stone or sand, by which the water is not only rendered more clear, but wholesome; for sand is insensibly dissolved by the water, so that in four or five years it will have lost a fifth part of its weight. Powder of charcoal should be added to the sponge when the water is foul, or fetid. Those who examine the large quantity of terrene matter on the inside of tea-kettles, will be convinced all water should be boiled before drunk, if they wish to avoid being afflicted with gravel and stone, &c.

To purify the muddy Water of Rivers or Pits.

Make a number of holes in the bottom of a deep tub; lay some clean gravel thereon, and above this some clean sand; sink this tub in the river or pit, so that only a few inches of the tub will be above the surface of the water; the river or pit water will filtre through the sand, and rise clear through it to the level of the water on the outside, and will be pure and limpid.

Method of making putrid Water sweet in a Night's Time.

Four large spoonsful of unslacked lime put into a puncheon of ninety gallons of putrid water, at sea, will, in one night, make it as clear and sweet as the best spring water just drawn; but unless the water is afterwards ventilated sufficiently to carbonize the lime, it will be a lime water. Three ounces of pure unslacked lime should saturate 90 gallons of water.

To prevent the Freezing of Water in Pipes in the Winter Time.

By tying up the ball cock, during the frost, the freezing of pipes will often be prevented; in fact, it will always be prevented where the main pipe is higher than the cistern or other reservoir, and the pipe is laid in a regular inclination from one to the other, for then no water can remain in the pipe; or if the main is lower than the cistern, and the pipe regularly inclines, upon the supplies ceasing, the pipe will immediately exhaust itself into the main. Where water is in the pipes, if each cock is left a little dripping, this circulation of the water will frequently prevent the pipes from being frozen.

Easy Method of purifying Water.

Take a common garden pot, in the midst of which place a piece of wicker work; on this spread a layer of charcoal of four or five inches in thickness, and above the charcoal a quantity of sand. The surface of the sand is to be covered with paper pierced full of holes, to prevent the water from making channels in it. This filtre is to be renewed occasionally. By this process, which is at once simple and economical, every person is enabled to procure pure limpid water at a very trifling expense.

The best Method of obtaining pure soft Water, for Medicinal Purposes, without distilling it.

Place an earthen pan in the fields, at a considerable distance from the smoke of any town, to catch the rain as it falls from the clouds. The water should be put into perfectly clean bottles, and the corks well secured with wax, and if the bottles are put into a cool place, the water will keep sweet for several years.

To purify River or any other Muddy Water.

Dissolve half an ounce of alum in a pint of warm water, and stirring it about in a puncheon of water just taken from any river, all the impurities will soon settle to the bottom, and in a day or two it will become as clear as the finest spring water.

Warm Water.

Warm water is preferable to cold water, as a drink, for persons who are subject to dyspeptic and bilious complaints, and it may be taken more freely than cold water, and consequently answers better as a diluent for carrying off bile, and removing obstructions in the urinary secretion in cases of stone and gravel. When water, of a temperature equal to that of the human body, is used for drink, it proves considerably stimulant, and is particularly suited to dyspeptic, bilious, gouty, and chlorotic subjects.

To make Sea Water fit for washing Linen at Sea.

Soda put into sea water renders it turbid; the lime and magnesia fall to the bottom. To make sea water fit for washing linen at sea, as much soda must be put in it, as not only to effect a complete precipitation of these earths, but to render the sea water sufficiently lixivial or alkaline. Soda should always be taken to sea for this purpose.

Proper Method of making Toast and Water, and the Advantages resulting therefrom.

Take a slice of fine and stale loaf bread, cut very thin (as thin as toast is ever cut), and let it be carefully toasted on both sides, until it be completely browned all over, but nowise blackened or burned in any way. Put this into a common deep stone or china jug, and pour over it, from the tea kettle, as much clean boiling water as you wish to make into drink. Much depends on the water being actually in a boiling state. Cover the jug with a saucer or plate, and let the drink cool until it be quite cold; it is then fit to be used: the fresher it is made the

better, and of course the more agreeable. The above will be found a pleasant, light, and highly diuretic drink. It is peculiarly grateful to the stomach, and excellent for carrying off the effects of any excess in drinking. It is also a most excellent drink at meals, and may be used in the summer time, if more agreeable to the drinker.

To make a Vessel for filtering Water.

Where water is to be filtered in large quantities, as for the purposes of a family, a particular kind of soft spongy stones, called filtering stones, are employed. These, however, though the water percolates through them very fine, and in sufficient quantity at first, are liable to be obstructed in the same manner as paper, and are then rendered useless. A better method seems to be, to have a wooden vessel lined with lead, three or four feet wide at top, but tapering so as to end in a small orifice at the bottom. The under part of the vessel is to be filled with very rough sand, or gravel, well freed from earth by washing; over this pretty fine sand may be laid, to the depth of twelve or fourteen inches, but which must likewise be well freed from earthy particles.

The vessel may then be filled up to the top with water, pouring it gently at first, lest the sand should be too much displaced. It will soon filtre through the sand, and run out at the lower orifice exceedingly transparent, and likewise in very considerable quantities. When the upper part of the sand begins to be stopped up, so as not to allow a free passage to the water, it may occasionally be taken off, and the earthy matter washed from it, when it will be equally serviceable as before.

The Turkish method of filtering Water by Ascension.

They make two wells, from five to ten feet, or any depth, at a small distance, which have a communication at the bottom. The separation must be of clay well beaten, or of other substances impervious to water. The two wells are then filled with sand and gravel. The opening of that into which the water to be filtered is to run must be somewhat higher than that into which the water is to ascend; and this must not have sand quite up to its brim, that there may be room for the filtered water; or it may, by a spout, run into a vessel placed for that purpose. The greater the difference is between the height of the two wells, the faster the water will filtre; but the less it is the better, provided a sufficient quantity of water be supplied by it.

This may be practised in a cask, tub, jar, or other vessel. The water may be conveyed to the bottom by a pipe, the lower end having a sponge in it, or the pipe may be filled with coarse sand.

It is evident that all such particles, which by their gravity are carried down in filtration by descent, will not rise with the water in filtration by ascension. This might be practised on board ships at little expence.

Receipt for two Gallons of Eau de Luce.

Take of the oil of amber, one ounce; of highly rectified spirit of wine, four pounds; put them into a bottle, and let them remain there five days, shaking the bottle from time to time, by which means the spirit will be strongly impregnated with the oil; then put into this impregnated spirit four ounces of the choicest amber, finely powdered, and let

it digest three days, by which means you will have a very rich tincture of amber.

The tincture of amber being thus made, take of the strongest spirit of sal-amoniac, sixteen pounds, and add it to the foregoing tincture, together with eight pounds of highly rectified spirit of wine.

Thus will you obtain the celebrated water called Eau de Luce, so greatly in request, and so useful in all faintings and lowness of spirits.

Wormwood Cordial by Distillation.

There are two sorts of wormwood cordial, distinguished by the epithets of greater and lesser.

Receipt for making ten gallons of the lesser composition of Wormwood Cordial.

Take of the leaves of dried wormwood, five pounds; of the lesser cardamon seeds, five ounces, of coriander seeds, one pound; of clean proof spirit, eleven gallons; water, one gallon; draw of ten gallons, or till the feints begin to rise, with a gentle fire. It may be dulcified with sugar or not, at pleasure.

Receipt for ten Gallons of the greater Composition of Wormwood Cordial.

Take of common and sea wormwood, dried, of each ten pounds; of sage, mint, and balm, dried, of each twenty handfuls; of the roots of galangal, ginger, calamus aromaticus, and coriander, of each three ounces; of cinnamon, cloves, and nutmegs, the lesser cardamoms and cubebs, of each two ounces. Cut and bruise the ingredients as they require; digest them twenty-four hours, in eleven gallons of fine proof spirit, and two gallons of water, and draw off ten gallons, or till the feints begin to rise, with a pretty brisk fire.

Cherry Brandy.

This liquor is greatly called for in town and country; and is made different ways. Some press out the juice of the cherries, and having dulcified it with sugar, add as much spirit to it as the goods will bear, or the price it is intended to be sold for. But the common method is, to put the cherries, clean picked, into a cask, with a proper quantity of proof spirit; and after standiug about eighteen days, the goods are drawn off into another cask for sale, and about two-thirds of the first quantity of spirits poured into the cask upon the cherries. This is to stand about a month to extract the whole virtue from the cherries, after which it is drawn off as before; and the cherries pressed to take out the spirit they had absorbed. The proportion of cherries and spirit is not very nicely observed; the general rule is, to let the cask be about half filled with cherries, and then filled up with proof spirits. Some add to every twenty gallons of spirit half an ounce of cinnamon, an ounce of cloves, and about three pounds of sugar, by which the flavour of the goods is considerably increased. But in order to save expences, not only the spices and sugar are generally omitted, but also a great part of the cherries, and the deficiency supplied by the juice of elderberries. Your own reason, therefore, and the price you can sell your goods for, must direct you in the choice of your ingredients.—By the same method you may make raspberry brandy; and if the colour of the goods be not deep enough, it may be improved by an addition of cherry brandy, elder juice, or other colouring substance, as log-wood, &c.

Raspberry Brandy

Is infused much after the same manner with cherry brandy, and drawn off, and made fit for sale with about the same addition of brandy to what you draw off from the first, second, and third infusion, and dulcified accordingly, first making it of a bright deep colour; but omitting cinnamon and cloves in the first, but not in the second and third infusion.

The first infusion will be of a colour deep enough without help or art to it; the second infusion will be somewhat paler, and must be made deeper coloured, by adding cherry brandy about a quart to ten or more gallons of the said raspberry brandy; and the third infusion will take more cherry brandy to colour the raspberry, which your own judgment will direct you in; here you may assist the colour and flavour with the juice of the elder-berry.

To make Elder Juice.

When you make elder juice let your berries be fully ripe, and all the stalks (which are very many) be clean picked from them; then if you have a press for drawing all the juice from them; have ready four hair cloths somewhat broader than your press, and lay one layer above another having a hair cloth betwixt every layer, which must be laid very thin, and pressed first a little, and then more, till your press be drawn as close as you can; then take out the berries, and press all you have in the like manner; then take your pressed berries, and break out all the lumps, and put them into an open-headed vessel, and put upon them as much liquor as will just cover them, and let them infuse so for seven or eight days, and put your best juice into a cask proper for it to be kept in, and put one gallon of malt spirits, not rectified, to every twenty gallons of elder juice, which will effectually preserve it from becoming sour for two years at least.

Spirituous Tinctures, or Infusions.

Rectified spirit of wine is the direct menstruum of the resins and essential oils of vegetables, and totally extracts these active principles from sundry vegetable matters, which yield them to water either not at all, or only in part.

It dissolves likewise the sweet saccharine matter of vegetable, and generally those parts of animal bodies, in which their peculiar smells and tastes reside.

The virtues of many vegetables are extracted almost equally by water and vitrified spirit; but in the watery and spirituous tinctures of them there is this difference, that the active parts, in the watery extractions, are blended with a large proportion of inert gummy matter, on which their solubility in this menstruum in great measure depends, while rectified spirit extracts them almost pure from gum. Hence, when the spirituous tinctures are mixed with watery liquors, a part of what the spirit had taken up from the subject generally separates and subsides, on account of its having been freed from that matter, which being blended with it in the original vegetable, made it soluble in water. This, however, is not universal; for the active parts of some vegetables, when extracted by rectified spirit, are not precipitated by water, being almost equally dissoluble in both menstrua.

Rectified spirit may be tinged by vegetables of all colours, except blue. The leaves of plants in general, which give out but little of their natural colour to watery liquors, communicate to spirit the whole of their green tincture, which, for the most part, proves elegant, though not very durable.

General Rules for Extracting Tinctures.

1. The vegetable substances ought to be moderately and newly dried, unless they are expressly ordered otherwise. They should likewise be cut and bruised before the menstruum is poured on them.

2. If the digestion be performed in balneo, the whole success depends upon a proper management of the fire; it ought to be all along gentle, unless the hard texture of the subject should require it to be augmented; in which case the heat may be increased so as to make the menstruum boil a little towards the end of the process.

3. Very large circulatory vessels ought to be employed for this purpose, which should be heated before they are luted together. Circulatory vessels are those which are so contrived, and of such a height, that the vapour, which arises during the digestion, may be cooled and condensed in the upper part, and fall down again into the liquor below; by these means the dissipation, both of the spirit and of the volatile parts of the ingredients, is prevented. They are generally composed of two long-necked matrasses, or bolt heads; the mouth of one of which is to be inserted into that of the other, and the juncture secured by a piece of wet bladder.

The use of heating the vessels is to expel a part of the air, which otherwise, rarifying in the process, would endanger bursting them or blowing off the uppermost matrass. A single matrass with a long neck, or with a glass pipe inserted into its mouth, is more commodious than the double vessel.

4. The vessel is to be frequently shaken during the digestion.

5. All tinctures should be suffered to settle before they are committed either to the filtre or strainer.

6. In the tinctures (and distilled spirits likewise) designed for internal use, no other spirit, drawn from malt, molasses, or other fermented matter, is to be used, than that expressly prescribed.

7. Resins and resinous gums yield tinctures more successfully, if, after being ground into powder, they be mixed with some white sand, well washed and dried, which will prevent their running into lumps by the heat. If the powders prescribed be sufficient for this purpose, such an addition is unnecessary.

Bitter Tincture.

Take of gentian root, two ounces; yellow rind of Seville orange peel, dried, one ounce; lesser cardamom seeds, freed from the husks, half an ounce; proof spirit, two pints; digest without heat, and strain off the tincture.

This is a very elegant spirituous bitter. As the preparation is designed for keeping, lemon peel is an excellent ingredient in the watery bitter infusions.

Stomachic Elixir.

Take of gentian root, two ounces; Curaçoa oranges, one ounce; Virginian snake root, half an ounce; cochineal, half a drachm; French brandy, two pints.

Let them steep for three days, and then filtre the elixir.

Method of Preserving Grapes.

Take a cask or barrel, inaccessible to the external air, and put into it a layer of bran, dried in an oven, or of ashes well dried and sifted. Upon this, place a layer of grapes well cleaned, and gathered in the afternoon of a dry day, before they are perfectly ripe. Proceed thus with alternate layers of bran and grapes, till the barrel is full, taking care that the grapes do not touch each other, and to let the last layer be of bran; then close the barrel, so that the air may not be able to penetrate, which is an essential point. Grapes, thus packed, will keep nine or even twelve months. To restore them to their freshness, cut the end of the stalk of each bunch of grapes, and put that of white grapes into white wine, and that of the black grapes into red wine, as you would put flowers into water, to revive or keep them fresh.

Singular and Simple Manner of Preserving Apples from the Effects of Frost, in North America.

Apples being produced most abundantly in North America, and forming an article of chief necessity in almost every family, the greatest care is constantly taken to protect them from frost at the earliest commencement of the winter season; it being well known, that apples, if left unprotected, are inevitably destroyed by the first frost which occurs. This desirable object, during their long and severe winters, is said to be completely effected, by only throwing over them a thin linen cloth before the approach of frost, when the fruit beneath is never injured, how severe soever the winter may happen to prove. Yet apples are there usually kept in a small apartment immediately beneath the roof of the house, particularly appropriated to that purpose, and where there is never any fire. This is a fact so well known, that the Americans are astonished it should appear at all wonderful: and they have some reason to be so, when it is considered that, throughout Germany, the same method of preserving fruit is universally practised; from whence, probably, it made its way to North America. It appears, that linen cloth only is used for this purpose; woollen cloth, in particular, having been experienced to prove ineffectual. There seems abundant reason to believe, that even potatoes might be protected from frost by some such simple expedient.

Remark.—This article, as well as the preceding (to which the principle seems very analogous), merits high consideration; and for the same important reason, its capability of conducing to the universal benefit of mankind, and the numerous animals under our protection.

To keep Oranges and Lemons.

Take small sand and make it very dry; after it is cold put a quantity of it into a clean vessel; then take your oranges, and set a laying of them in the same, the stalk end downwards, so that they do not touch each other, and strew in some of the sand, as much as will cover them.

two inches deep; then set your vessel in a cold place, and you will find your fruit in high preservation at the end of several months.

To make an excellent Smelling Bottle.

Take an equal quantity of sal-ammoniac and unslacked lime, pound them separate, then mix and put them in a bottle to smell to. Before you put in the above, drop two or three drops of the essence of burgamot into the bottle, then cork it close. A drop or two of ether, added to the same will greatly improve it.

To make Milk of Roses.

To one pint of rose water, add one ounce of oil of almonds, and ten drops of the oil of tartar.

N. B. Let the oil of tartar be poured in last.

Wash for the Skin.

Four ounces of potass, four ounces of rose water, two ounces of pure brandy, and two ounces of lemon juice; put all these into two quarts of water, and when you wash, put a table spoonful or two of the mixture into the bason of water you intend washing in.

Method of extracting Essences from Flowers.

Procure a quantity of the petals of any flowers which have an agreeable fragrance; card thin layers of cotton, which dip into the finest Florence or Lucca oil; sprinkle a small quantity of fine salt on the flowers, and lay them, a layer of cotton, and a layer of flowers, until an earthen vessel or a wide-mouthed glass bottle is full. Tie the top close with a bladder, then lay the vessel in a south aspect to the heat of the sun, and in fifteen days, when uncovered, a fragrant oil may be squeezed away from the whole mass, little inferior (if that flower is made use of) to the dear and highly valued Otto or Odour of Roses.

To make the Quintessence of Lavender, or other Aromatic Herb.

Take off the blossoms from the stalks, which must be cut fresh at sun-rising in warm weather; spread the blossoms on a white linen cloth, and lay them in the shade for twenty-four hours; after which, stamp or bruise them; then put them, immersed in warm water, into the still, near a fire, and let them infuse for the space of five or six hours, so closely covered that nothing may exhale from it; after which time, take off the covering, and quickly put on the helm, and lute it carefully. You must, in the beginning, draw over half the quantity of the water you put in. If you take away the receiver, you will see the quintessence on the surface of the water, which you may easily separate from it. Then put the distilled water back again, and distil it over again, till there appear no more of the quintessence on the water. You may distil this water four or five times over, according as you perceive the quintessence upon it.

The best distilling utensils for this work are those for the *balneum mariæ*, or sand bath; meanwhile you may, after the common method, distil the ingredients on an open fire. But if you intend to make quintessence for waters, you may make use of common salt, in order to extract the more quintessence of any blossom.

Take four pounds of blossoms of any aromatic plant, and infuse in it six quarts of water. If you use salt to bring your infusion to a ferment, add half a pound of common salt to it.

To obtain Aromatic Oils from the Pellicle which envelopes the Seeds of the Laurus Sassafras, and Laurus Benzoin.

The method of obtaining these oils is, to boil the pellicle which surrounds the seeds of the sassafras and benjamin-tree in water; when they float upon its surface, from which they may be skimmed with a spoon.

That of the sassafras differs materially from the oil obtained from the bark of the root of this tree. Its aroma is different, it is much lighter, and it congeals in a higher degree of heat.

The oil of the benzoin tree is a delightful aromatic, is very inflammable, and might be used as a spice in food, and in all those diseases in which the aromatic oils are useful. It has been tried with success, as an external application, in a case of severe chronic rheumatism. One half pound of the pellicle of the seeds will yield several ounce-measures of oil.

To preserve Aromatic and other Herbs.

The boxes and drawers in which vegetable matters are kept should not impart to them any smell or taste; and more certainly to avoid this they should be lined with paper. Such as are volatile, of a delicate texture, or subject to suffer from insects, must be kept in well covered glasses. Fruits and oily seeds, which are apt to become rancid, must be kept in a cool and dry, but by no means in a warm and moist place.

Another Receipt for Lavender Water.

Put two pounds of lavender pips into two quarts of water, put them into a cold still, and make a slow fire under it; distil it off very slowly, and put it into a pot till you have distilled all your water; then clean your still well out, put your lavender water into it, and distil it off slowly again; put it into bottles, and cork it well.

Another.

Take a pint of the best rectified spirits of wine, a shilling's worth of oil of lavender, sixpennyworth of essence of ambergris; mix these altogether, and keep it close from the air, then draw it off for use.—Let it stand till it is fine before you draw it off.

To make Rose Water.

Gather roses on a dry day, when they are full blown; pick off the leaves, and to a peck put a quart of water, then put them into a cold still, make a slow fire under it; the slower you distil it the better it will be; then bottle it, and in two or three days you may cork it.

To make Eau de Luce, and its Use.

Take of spirit of wine one ounce, spirit of sal-ammoniacum four ounces, oil of amber one scruple, white Castile soap ten grains. Digest the soap and oil in the spirits of wine, add the ammoniacum, and shake them well together.

To make Hungary Water.

Take a quantity of the flowers of rosemary, put them into a glass retort, and pour in as much spirit of wine as the flowers can imbibe; dilute the retort well, and let the flowers macerate for six days, then distil it in a sand heat.

To make Otto (or Odour) of Roses.

Pick the leaves of roses from all seeds and stalks, put them in a clean earthen vessel, glazed within, or a clean wooden vessel. Pour spring water on them, so as to cover them; set the vessel in the sun in the morning at rising, and leave it in the sun-shine till sun-set; then take them into the house; repeat this for six or seven days, and in three or four days there will be a fine yellow oily matter on the surface of the water; and, in two or three days more, there will appear a scum upon the surface, which is the otto of roses. This may be taken up with cotton, and squeezed into a phial with the finger and thumb.

Remark.—It is suspected that there is some mistake in this receipt, and it has passed to the public through very many hands. It was published in the Transactions of the Royal Society of Edinburgh, on the authority of Dr. D. Monro, of London, who received it from Major Mackenzie, who again got it from an officer of his corps, whose name is not mentioned.

The account given by Polier in the Transactions of the Bengal Society is very different. It is needless to detail it, for it is exactly the process of an European distiller: cohobation on fresh leaves, and exposure to slight cold, to congeal the essential oil, which is skimmed off or taken up by cotton, and squeezed into phials.

It is conjectured, that in the manufacture or production of otto, which is thought to be profitable in the East, and the reverse in Europe, the difference cannot be in the price of labour, or similar circumstances, which European skill would more than compensate; but in the fact, that there is a market for rose-water in the East, from the quantity used in washing hands, sprinkling rooms and garments, and similar purposes, to which the demand of the European apothecary and confectioner is comparatively insignificant. It is but a thin film of congealed essential oil which a great quantity of rose water will afford; and after it is taken off, the water is still very good. In India it may be sold; in Europe it is waste; for to employ it in fresh distillations is clearly to waste a manufactured article.

To prepare Aromatic Vinegar.

Take of common vinegar any quantity; mix a sufficient quantity of powdered chalk, or common whitening, with it, to destroy the acidity. Then let the white matter subside, and pour off the insipid, supernatant liquor; afterwards let the white powder be dried, either in the open air, or by a fire. When it is dry, pour upon it sulphuric acid (oil of vitriol), as long as white acid fumes continue to ascend. Stone vessels are the properest to be used on this occasion, as the acid will not act upon them. This product is the acetic acid, known in the shops by the name of aromatic vinegar. The simplicity and cheapness of this process points it out as a very useful and commodious one for purifying

prisons, hospital-ships, and houses, where contagion is presumed or suspected, the white acid fumes diffusing themselves quickly around.

If any one is desirous of obtaining the acid in a liquid state, the apparatus of Nooth presents a convenience for the purpose. It must of course be collected in water. But the muriatic acid is cheaper, and much more expansible.

Preparation of the Greek Water (or the Solution of Silver, for the converting red or light-coloured Hair into a deep Brown.)

Take silver filings, and dissolve them in spirit of nitre. The spirit of nitre and the silver being put in a matrass, must be placed, first, in a gentle sand-heat, and afterwards removed where the fluid may be made to boil for a short time. Being taken out of the sand-heat, while yet hot, add as much water as may have evaporated during the boiling; and, when the solution is grown cold, decant off the clear fluid from the sediment, if there be any, and the undissolved part of the silver filings; which may be dissolved afterwards, by adding more spirit of nitre, and repeating the same treatment.

(Lunar caustic dissolved in water is precisely the same. It is sold by the chemists for about half-a-crown an ounce: the salt is more pure and cheaper than it can be made in small quantities.)

The solution of silver, thus obtained, with common water, is the Greek water, used for turning red or light coloured hair to brown. Its efficacy may be greatly improved by washing the hair before the application of the water, with common water, in which some soda has been dissolved. The proportion may be an ounce and an half of pure soda to a pint of the water; but it requires a frequent repetition to change the colour of the hair; and care must be taken that a sufficient quantity of water be added to dilute the solution, to prevent its destroying the hair, or, perhaps, excoriating the skin by its causticity. At least douhle the quantity of water should be therefore added.

The hair must first be cleaned from powder and pomatum, with a small tooth comb, and then washed with the soda and water till all grease, pomatum, &c. be got out; then use the Greek water in the following manner, first shaking the bottle: Take as much hair as can conveniently be wetted, and with a bit of sponge, tied on a little stick dipped in the Greek water, wet the hair well, and so proceed till all is wetted; let it dry by sun, air, or fire, before you repeat it, which must be done four times, and must afterwards be washed with the soda and water, all which may easily be done in eight hours. A cloth should be put on the shoulders, and do not let the Greek water touch the skin, or as little as possible. To make yourself expert, first try, according to the above directions, to dye a lock of hair that is not growing on the head; and make the Greek water stronger or weaker, according as you find it necessary.

A more convenient Dye for the Hair.

The defect of the preceding composition is, that it stains the skin as well as the hair—this inconvenience does not attend the following preparation:

Into a glass phial or a porcelain or clean-glazed earthen-ware vessel, filled with strong clear lime water, put a little litharge in fine powder. The lime water will dissolve a portion of the litharge in the cold, and

a greater quantity by the application of a boiling heat. When the solution is complete, pour it into a bottle, and keep it stopped. More lime water may be put to the remaining litharge. By evaporation in a retort, the solution is concentrated, and yields very small transparent crystals, about as soluble in water as lime.

It blackens the hair and the nails; but as it does not effect the colour of the skin, nor of animal oils, it may be applied every time that the face is washed, or the hair combed. It is decomposed by the sulphats of alkalies and sulphurated hydrogen gas.

British Champaigne.

Take gooseberries before they are ripe, crush them with a mallet in a wooden bowl, and to every gallon of fruit put a gallon of water; let it stand two days, stirring it well; squeeze the mixture well with your hands through a hop-sieve; then measure your liquor, and to every gallon put three pounds and a half of loaf sugar; mix it well in the tub, and let it stand one day: put a bottle of the best brandy in the cask; leave the cask open five or six weeks, taking off the scum as it rises; then make it up, and let it stand one year in the barrel before bottled.

N. B. One pint of brandy is put to seven gallons of liquor.

To make Koumiss, a valuable Wine of the Tartars.

Take of fresh mare's milk, of one day, any quantity; add to it a sixth part water, and pour the mixture into a wooden vessel; use then, as a ferment, an eighth-part of the sourest cow's milk that can be got; but at any future preparation, a small portion of old koumiss will better answer the purpose of souring. Cover the vessel with a thick cloth, and set it in a place of moderate warmth; leave it at rest twenty-four hours: at the end of which time the milk will have become sour, and a thick substance will be gathered on its top; then, with a stick, made at the lower end in the manner of a churn staff, beat it till the thick substance above-mentioned be blended intimately with the subjacent fluid. In this situation leave it again at rest for twenty-four hours more; after which, pour it into a higher and narrower vessel, resembling a churn, where the agitation must be repeated as before, till the liquor appear to be perfectly homogeneous; and in this state it is called koumiss; of which the taste ought to be a pleasant mixture of sweet and sour. Agitation must be employed every time before it is used. This wine operates as a cooling antiseptic, an useful stimulant, cordial, and tonic, and may prove a valuable article of nourishment; and it has one excellence, perhaps not the least, that the materials from which it is prepared are cheap, and the mode of preparation simple.

Another Orange Wine.

Take the expressed juice of eight Seville oranges; and, having one gallon of water wherein three pounds of sugar have been boiled, boil the water and sugar for twenty minutes; skim constantly, and when cooled to a proper heat for fermentation, add the juice, and the outer rind of the juice (fruit) shaved off. Put all into a barrel, stir it frequently for two or three days, and then closely bung it for six months before it is bottled.

Excellent American Wine.

The following receipt was originally communicated to the public by Joseph Cooper, Esq. of New Jersey, North America:

"I put a quantity of the comb, from which the honey had been drained, into a tub, and added a barrel of cyder, immediately from the press; this mixture was well stirred, and left for one night. It was then strained before a fermentation took place; and honey was added, until the strength of the liquor was sufficient to bear an egg. It was then put into a barrel; and after the fermentation commenced, the cask was filled every day, for three or four days, that the filth might work out of the bung-hole. When the fermentation moderated, I put the bung in loosely, lest stopping it tight might cause the cask to burst. At the end of five or six weeks, the liquor was drawn off into a tub; and the whites of eight eggs, well beat up, with a pint of clean sand, were put into it: I then added a gallon of cyder spirit; and after mixing the whole well together, I returned it into the cask, which was well cleaned, bunged it tight, and placed it in a proper situation for racking off, when fine. In the month of April following, I drew it off into kegs, for use; and found it equal, in my opinion, to almost any foreign wine: in the opinion of many judges, it was superior.

"This success has induced me to repeat the experiment for three years; and I am persuaded, that, by using clean honey, instead of the comb, as above described, such an improvement might be made, as would enable the citizens of the United States to supply themselves with a truly federal and wholesome wine, which would not cost a quarter of a dollar per gallon, were all the ingredients procured at the market price; and would have this peculiar advantage over every other wine, hitherto attempted in this country, that it contains no foreign mixture, but is made from ingredients produced on our own farms."

Aromatic Tincture.

Take of cinnamon, six drachms; lesser cardamom-seeds, freed from husks, three drachms; long pepper and ginger, of each two drachms; proof spirit, two pints. Digest without heat, and then strain off the tincture.

This is a very warm aromatic, too much so to be given without dilution. A tea-spoonful or two may be taken in wine, or any other convenient vehicle, in languors, weakness of the stomach, flatulencies, and similar complaints.

The stomachic tincture, described hereafter, is similar in intention to this, but contrived less hot of the spices, that it may be taken by itself:

Take of cinnamon, six drachms; lesser cardamom-seeds, one ounce; garden angelica-root, three drachms; long pepper, two drachms; proof spirit, two pounds and a half.

Macerate seven days, and filtre.

This preparation is improved from the preceding editions of the pharmacopiea, by the omission of some articles either superfluous or foreign to the intention; galangal, gentian, zedoary, and bay berries. As now reformed, it is a sufficiently elegant warm aromatic.

Of making Compounds or Cordials.

The perfection of this grand branch of distillery depends upon the observation of the following general rules, easy to be observed and practised.

1. The artist must always be careful to use a well cleansed spirit, or one freed from its own essential oil, as were before observed.

For as a compound cordial is nothing more than a spirit impregnated with the essential oil of the ingredients, it is necessary that the spirit should have deposited its own.

2. Let the time of previous digestion be proportioned to the tenacity of the ingredients, or the ponderosity of their oil. Thus cloves and cinnamon require a longer digestion before they are distilled than calamus aromaticus, or orange-peel. Sometimes cohobation (as subsequently explained) is necessary; for instance, in making the strong cinnamon cordial, because the essential oil of cinnamon is so extremely ponderous, that it is difficult to bring over the helm with the spirit without cohobation.

3. Let the strength of the fire be proportioned to the ponderosity of the oil intended to be raised with the spirit. Thus, for instance, the strong cinnamon cordial requires a much greater degree of fire than that from lax vegetables, as mint, balm, &c.

4. Let a due proportion of the finest parts of the essential oil be united with the spirit; the grosser and less fragrant parts of the oil not giving the spirit so agreeable a flavour, and at the same time renders it thick and unsightly. This may in a great measure be effected by leaving out the feints, and making up to proof with fine soft water in their stead.

These four rules, carefully observed, will render this extensive part of distillation far more perfect than it is at present. Nor will there be any occasion for the use of burnt alum, white of eggs, isinglass, &c. to fine down cordials, for they will presently be fine, sweet, and pleasant tasted, without any further trouble.

Receipt for Sixteen Gallons of Strong Cinnamon Cordial.

Cinnamon is a very useful and elegant aromatic bark, of a fragrant delightful smell, and sweet pungent taste, with some degree of astringency; it corroborates the viscera, and proves of great service in als kinds of alvine fluxes, and immoderate discharges from the uterus; it il cordial and stomachic.

Take eight pounds of fine cinnamon, bruised; seventeen gallons of clear rectified spirit, and two gallons of water. Put them into your still, and digest them twenty-four hours with a gentle heat; after which, draw off sixteen gallons by a pretty strong heat.

I have ordered a much larger quantity of cinnamon than is common among distillers; because when made in the manner above directed, it is justly looked upon as one of the noblest cordials of the shops; but when made in the common way, of two pounds to twenty gallons of spirit, as some have ordered, is only an imposition on the buyer.

Receipt for Ten Gallons of Hungary Water.

Rosemary, the principal ingredients in Hungary water, has always been a favourite shrub in medicine; it is full of volatile parts, as appears by its taste and smell. It is a very valuable cephalic, and is good

in all disorders of the nerves; in hysteric and hypochondriac cases, in palsies, apoplexies, and vertigoes. Some suppose that the flowers possess the virtues of the whole plant in a more exalted degree than any other part; but the flowery tops, leaves, and husks, together with the flowers themselves, are much fitter for all purposes than the flowers alone.

Take of the flowery top, with the leaves and flowers of rosemary, fourteen pounds; rectified spirit, eleven gallons and a half; water, one gallon; distil off ten gallons with a moderate fire. If you perform this operation in balneum mariæ, your Hungary water will be much finer than if drawn by the common alembic.

This is called Hungary water, from its being first made for a princess of that kingdom.

Some add lavender flowers, and others florentine orange-root; but what is most esteemed is made with rosemary only.

Receipt for Ten Gallons of Simple Lavender Water.

Take fourteen pounds of lavender flowers, ten gallons and a half of rectified spirit of wine, and one gallon of water; draw off ten gallons with a gentle fire, or, which is much better, in balneum mariæ.

Both the Hungary and lavender water may be made at any time of the year, without distillation.

Receipt for making Three Gallons of Compound Lavender Water.

Take of lavender water above described, two gallons; of Hungary water, one gallon; cinnamon and nutmegs, of each three ounces; and of red saunders, one ounce; digest the whole three days in a gentle heat, and then filtre it for use. Some add saffron, musk, and ambergris, of each half a scruple; but those are now generally omitted.

Receipt for Ten Gallons of Cardamom Cordial.

The seed from whence this cordial takes its name, is called by botanists cardamomum minus, or the lesser cardamom; to distinguish it from the cardamomum majus, or grains of paradise.

The lesser cardam is a small short fruit, or membraneous capsule, of a triagonal form, about a third of an inch long, and swelling out thick about the middle, beginning small and narrow from the stalk, and terminating in a small but obtuse point at the end. It is striated all over very deeply with longitudinal furrows, and consists of a thin but very tough membrane, of a fibrous texture, and pale brown colour, with a faint cast of red.

When the fruit is thoroughly ripe, this membrane opens at the three edges all the way, and shows that it is internally divided by three thin membranes into three cells, in each of which is an arrangement of seeds, separately lodged in two series. The seeds are of an irregular angular figure, rough, and of a dusky brown colour on the surface, with a mixture of yellowish and reddish, and of a white colour within. They have not much smell, unless first bruised, when they are much like camphire under the nose. They are of an acid, aromatic, and fiery hot taste. They should be chosen sound, close shut on all sides, and full of seeds of a good smell and of an acrid aromatic taste.

Take of the lesser cardamom seeds, husked, two pounds and a half; of clean proof spirit, ten gallons and a half; and of water one gallon;

draw off ten gallons by a gentle heat. You may either dulcify it or not with fine sugar, at pleasure.

This water is carminative, assists digestion, and is good to strengthen the head and stomach. A tincture or infusion is still better.

Receipt for a Gallon of Jamaica Pepper Water.

Jamaica pepper is the fruit of a tall tree growing in the mountainous parts of Jamaica, where it is much cultivated, because of the great profit arising from the cured fruit, sent in large quantities annually into Europe.

Take of Jamaica pepper, half a pound; water, two gallons and a half; draw off one gallon with a pretty brisk fire. The oil of this fruit is very ponderous, and therefore this water is best made in an alembic.

Receipt for Five Quarts of Compound Gentian Water.

Gentian root, sliced, three pounds; leaves and flowers of the lesser centaury, of each eight ounces; infuse the whole in six quarts of proof spirits, and one quart of water; and draw off the water till the feints begin to rise. This water is frequently used as being a very fine stomachic.

Distilled Spirituous Waters.

By distilled spirits are understood such as are drawn with a spirit that has been previously rectified, or which is reduced nearly to that strength in the operation; by spirituous waters, those in which the spirit is only of the proof strength, or contains an admixture of about an equal measure of water. These last have been usually called compound waters, even when distilled from one ingredient only; as those on the other hand, which are drawn by common water, though from a number of ingredients, are named simple; the title simplex, here relating not to simplicity in respect of composition, but to the vehicles being plain water.

General Rules for the Distillation of Spirituous Waters.

1. The plants and their parts ought to be moderately and newly dried, except such as are ordered to be fresh gathered.

2. After the ingredients have been steeped in the spirit for the time prescribed, add as much water as will be sufficient to prevent a burnt flavour, or rather more.

3. The liquor which comes over first in the distillation is by some kept by itself, under the title of spirit; and the other runnings, which prove milky, fined down by art. But it is better to mix all the runnings together, without fining them, that the waters may possess the virtues of the plant entire; which is a circumstance to be more regarded than their fineness or sightliness.

4. In the distillation of these waters, the genuine brandy obtained from wine is directed.

Where this is not to be had, take, instead of that proof spirit, half its quantity of a well rectified spirit, prepared from any other fermented liquors. In this steep the ingredients, and then add spring water enough, both to make up the quantity ordered to be drawn off, and to prevent burning.

By this method, more elegant waters may be obtained than when any of the common proof spirits, even that of wine itself, are made use of. All vinous spirits receive some flavour from the matter from which they are extracted; and of this flavour, which adheres chiefly to the phlegm or watery part, they cannot be divested without separating the phlegm, and reducing them to the rectified state of spirits of wine.

Receipt for Ten Gallons of Lemon Water.

The peel of the lemon, the part used in making this water, is a very grateful bitter aromatic, and on that account very serviceable in repairing and strengthening the stomach.

Take dried lemon-peel four pounds, clean proof spirit ten gallons and a half, and one gallon of water. Draw off ten gallons by a gentle fire. Some dulcify lemon water, but by that means its virtues, as a stomachic, are greatly impaired.

Receipt for One Gallon of Jessamine Water.

There are several species of jessamine, but that sort intended here is what gardeners call Spanish White, or Catalonian jessamine. This is one of the most beautiful of all the species of jessamine.

Take of Spanish jessamine flowers, twelve ounces; essence of florentine citron, or burgamot, eight drops; fine proof spirit, one gallon; water, two quarts. Digest two days in a close vessel, after which draw off one gallon, and dulcify with fine loaf sugar.

Receipt for One Gallon of Spirit of Scurvygrass.

Scurvygrass fresh gathered and bruised, fifteen pounds; horse-radish root, six pounds; rectified spirit of wine, one gallon; and three pints of water; digest the whole in a close vessel two days, and draw off a gallon with a gentle fire.

This is of great service in all scorbutic cases, and is given from twenty to eighty drops.

Antiscorbutic Water.

Take of the leaves of water cresses, garden and sea scurvygrass, and brook-lime, of each twenty handfuls; of pine tops, germander, horehound, and the lesser centaury, of each sixteen handfuls; of the roots of bryony and sharp pointed dock, of each six pounds; of mustard seed, one pound and a half. Digest the whole in ten gallons of proof spirit, and two gallons of water, and draw off by a gentle fire.

This is a fine water for the purposes mentioned in the title, against scorbutic disorders. As also in tremblings, and disorders of the nerves.

Profits upon a Tun of Gin.

A tun of fine gin, strength 1 to 7 over proof - - -	252 gallons.
When lowered to proof, gives water - - - - - -	36
Which, added together, make - - - - - - - - -	288 proof;
and it is further reduced to 1 in 5 below hydrometer proof, with water, which gives - - - - - - -	57
Total	345 gallons.

This done, let a pound of alum be just covered with water, and dissolved by boiling; rummage the above well together, and pour in the alum, and the whole will be fine in a few hours.

To ascertain the true cost, after the business is done, supposing the price you give for the tun of 252 gallons, at 14s. per gallon, is - - - - - - - - - - - - - - - - - - £176 8 0

252 gallons, reduced to 1 in 5 under proof, gives 345 gallons at 12s. per gallon	207 0 0
	176 8 0
Profit on 345 gallons	£ 30 12 0

To make Ten Gallons of Gin Bitters.

Take ten gallons of common gin, spirits of wine half a pint, in which dissolve the following essential oils, with the assistance of a little well dried loaf sugar, finely powdered, viz. essence of lemon and orange peel, of each an ounce; oil of wormwood, a quarter of an ounce; orange-peel dried, one pound; let them digest without heat for fourteen or fifteen days, then draw off for use as wanted; taking care not to disturb the goods, by stirring the vessel they are made in.

This will be a most pleasant cheap bitter, equally wholesome, and as good as many that are much dearer.

This is only fit to be taken with gin. The same ingredients, and rectified malt spirits, or molasses' spirits, will either of them make a bitter of more general use.

To make Two Gallons of Rum Shrub.

Take one gallon of rum, at one in eight: of lemon and orange juice, each one pint; one quart of orange wine; and two pounds of loaf sugar; one orange and lemon peel; and fill up your two gallon vessel with water, cork it up loosely, and let it stand until fine, then cork it down close.

To make Two Gallons of Brandy Shrub.

Take one gallon and a pint of brandy, one in eight; lemon and orange juice, of each a pint; four orange and two lemon peels; sugar, two pounds; compound essence of orange and lemon peel, a small tea-spoonful; make up with fair water, and let it stand till fine. Be careful in drawing it off not to shake the vessel.

To make Twenty Gallons of Peppermint Cordial.

Take thirteen gallons of rectified spirits, one in five under hydrometer proof; twelve pounds of loaf sugar; one pint of spirit of wine, that will fire gunpowder; fifteen pennyweights Troy of oil of peppermint; water, as much as will fill up the cask, which should be set up on end, after the whole being well roused, and a cock for drawing off placed in it.

To make up the above.

Powder two or three ounces of sugar in a brass mortar, on which pour the oil of peppermint, and beat it into a thin paste, stirring the sugar and oil with a knife, scraping what is in the pestle and mortar together, that the oil may be uniformly incorporated with the sugar;

then add the spirit of wine, and blend them well together; have the remainder of your sugar ready dissolved in four or five gallons of the water to be used for making up; rummage, or rouse, the whole well together with a paddle-staff, or rouser; and lastly, fill up the cask with pure clean water; dissolve one ounce and a half of powdered alum in the making up water, boiling over the fire; and when blood warm, add it to fill up the cask, in which place a cock, and let it stand two or three days, in which time it will be fit for use.

If the essential oil is of your own making, or such as you can depend on, it will require nothing more than agitation.

To make Twenty Gallons of Aniseed Cordial.

Take fourteen gallons of spirits, one in six; a pint of spirit of wine, strong as the former; from six to eight pounds of loaf sugar; one ounce and an half of oil of aniseed; two ounces of finely powdered alum; dissolve the sugar in one part of the water used for making up, and your alum in the remainder; and proceed as directed in the making up peppermint cordial. Aniseed cordial does not bear to be reduced much below one in five, as part of the oil will separate when too much lowered, and render the goods unsightly.

To make Two Gallons of Nauyau.

One gallon and an half of French brandy, one in five; six ounces of the best fresh prunes; two ounces of celery; three ounces of the kernels of apricots, nectarines, and peaches; and one ounce of bitter almonds; all gently bruised; essence of orange-peel, and essence of lemon peel, of each two pennyweights, killed in the same manner as the oil of peppermint; half a pound of loaf sugar; let the whole stand ten days or a fortnight; then draw off, and add to the clear Nauyau as much rose water as will make it up to two gallons, which will be about half a gallon.

To make Two Gallons of Cinnamon Cordial.

Take two pennyweights of oil of cassia-lignea, killed as before mentioned, with sugar and spirits of wine; a gallon and an half, at one in six; cardamum seeds, husked, an ounce; orange and lemon peel dried, of each an ounce; fine with half a pint of alum water; sweeten to your palate with loaf sugar, not exceeding two pounds, and make up two gallons measure with the water you dissolve the sugar in. This is a very cheap and elegant cinnamon cordial; colour with burnt sugar.

To make Twenty Gallons of Carraway Cordial.

Take an ounce and an half of oil of carraway; twenty drops of cassia-lignea oil, and five drops of essence of orange peel, and the same quantity of the essence of lemon; thirteen gallons of spirits, one in five: eight pounds of loaf sugar; make it up and fine it down, as directed for aniseed.

To make Twenty Gallons of Citron Cordial.

Infuse fourteen pounds of Smyrna figs, for a week, in twelve gallons of spirits, one in five; draw off, and add to the clear spirituous infusion essence of orange and lemon, of each an ounce, killed in a pnt of spirits of wine; half a pound of dried lemon, and four ounces

of orange peel; six or seven pounds of loaf sugar: make up as before, with fair water.

To make Twenty Gallons of Imperial Ratafia.

In these kingdoms the most compendious way of making the best ratafia is, by taking three quarters of a pound of the kernels of peaches, nectarines, and apricots, bruised; three pounds of bitter almonds, bruised; half a gallon of rectified spirit of wine, in which dissolve half an ounce of compound essence of ambergris; twelve gallons of pure molasses spirit, one in four gallons of British Frontiniac wine; and as many gallons of rose water as will make up the ratafia to twenty gallons; steep the kernels and almonds for ten days, then draw off for use. This quantity will take ten pounds of loaf sugar to sweeten it; but as some may not like it so, it had better be sweetened by a few gallons at a time, as it may be wanted.

Receipt for making Red Ratafia.

Take of cherries and gooseberries, of each thirty pounds; mulberries, seven pounds; raspberries, ten pounds. Pick all these fruits clean from their stalks, &c. bruise them, and let them stand twelve hours; but do not suffer them to ferment. Press out the juice, and to every pint add three ounces of sugar; when the sugar is dissolved, run it through the filtering bag, and to every five pints of liquor add four pints of clean proof spirit; together with the same proportion of spirit drawn from spices.

Different distillers use different quantities of the spirit drawn from spices. The best method, therefore, is to imitate the flavour most universally approved of, which may be easily done, by adding a greater or less proportion of the spiced spirit.

To make the Spicy Spirit.

Take of mace, one pound; nutmegs, four ounces; spirit, three gallons; and draw off the whole in balneum mariæ.

Lovage Cordial, Twenty Gallons.

Take of the fresh roots of lovage, valerian, and celery, and sweet fennel, each four ounces; of essential oil of carraway and savin, each one ounce; spirit of wine, one pint; twelve gallons of proof spirits; loaf sugar, twelve pounds; steep the roots and seeds in the spirits fourteen days; and kill, or dissolve, the oils in the spirit of wine, and add them to the undulcified cordial drawn off from the other ingredients; dissolve the sugar in the water for making up; fine, if necessary, with alum.

Nectar, a Twenty Gallon Cask.

A pleasant cordial for those whose stomach cannot bear a stronger, particularly if taken in the morning, for gently exhilarating the spirits, and strengthening the animal functions, may be advantageously made with fifteen gallons of the imperial ratafia, a quarter of an ounce of cassia-oil, and an equal quantity of the oil of carraway seeds, dissolved in half a pint of spirit of wine, and made up with orange wine, so as to fill up the cask.

Sweeten, if wanted, by adding a small lump of sugar in the glass.

Receipt for Ten Gallons of Common Usquebaugh by Distillation.

Usquebaugh is a very celebrated cordial, the basis of which is saffron. There are different ways of making this famous Irish cordial; but the following are equal to any I have seen:

Take of nutmegs, cloves, and cinnamon, of each two ounces; of the seeds of anise, carraway, and coriander, each four ounces; liquorice-root, sliced, half a pound; bruise the seeds and spices, and put them together with the liquorice into the still, with eleven gallons of proof spirits, and two gallons of water; distil with a pretty brisk fire till the feints begin to rise. But as soon as your still begins to work, fasten to the nose of the worm two ounces of English saffron, tied up in a cloth, that the liquor may run through it, and extract all its tincture; and, in order to this, you should often press the saffron with your fingers. When the operation is finished, dulcify your goods with fine sugar.

Receipt for making Ten Gallons of Usquebaugh by Digestion.

Take of raisins, stoned, five pounds; figs, sliced, one pound and a half; cinnamon, half a pound; nutmegs, three ounces; cloves and mace, of each one ounce and a half; liquorice, two pounds; saffron, four ounces; bruise the spices, slice the liquorice, and pull the saffron in pieces; digest these ingredients eight days in ten gallons of proof spirit, in a vessel close stopped; then filtre the liquor, and add to it two gallons of canary wine, and half an ounce of the tincture of ambergris.

Receipt for making Ten Gallons of Royal Usquebaugh by Distillation.

Take of cinnamon, ginger, and coriander seed, each three ounces; nutmegs, four ounces and an half; mace, cloves, and cubebs, of each one ounce and an half. Bruise these ingredients, and put them into an alembic, with lemon and orange peel, pared off thin, four ounces of each dried, or double the quantity of fresh peeled, and eleven gallons of proof spirit and two gallons of water, and distil till the feints begin to rise; fastening four ounces and an half of English saffron, tied in a cloth, to the end of the worm, that the liquor may run through it.

Take raisins stoned, four pounds and a half; dates, three pounds; liquorice rod, sliced, two pounds; digest these twelve hours in two gallons of water; strain out the clear liquor, add it to that obtained by distillation, and dulcify the whole with fine sugar.

Vinous Spirits.

These spirits are the lightest of almost all known liquors; expressed oils, which swim upon water, sink in these to the bottom; a measure which contains ten ounces by weight of water, will hold little more than eight and a quarter of pure spirit. The uses of vinous spirits, as menstrua for the virtues of other medicines, we have seen, and in this place consider only their own.

Pure alcohol coagulates all the fluids of animal bodies, except urine, and hardens the solid parts; applied externally, it strengthens the vessels, thickens the juices in them, and thus powerfully restrains hæmorrhages. It instantly contracts the extremities of the nerves it touches, and deprives them of sense and motion, by these means easing them of pain, but at the same time destroying their use. Hence employing spirituous liquors in fomentation (notwithstanding the specious titles of vivifying,

heating, restoring mobility, resolving, dissipating, and the like, usually attributed to them) may sometimes be attended with unhappy consequences. These liquors, received undiluted into the stomach, produce the same effects, thickening the fluid and contracting all the solid parts which they touch, and destroying, at least for a time, their use and office: if the quantity be considerable, a palsy or apoplexy follows, which ends in death. Taken in a small quantity, and duly diluted, they brace up the fibres, raise the spirits, and promote agility; if further continued, the senses are disordered, voluntary motion destroyed, and at length the same inconveniences brought on as before. Vinous spirits, therefore, in small quantities, and properly diluted, may be applied to useful purposes in the cure of diseases; whilst in larger ones, or if their use be long continued, they act as a poison of a particular kind.

CHAP. XXIV.

MISCELLANEOUS.

To make Phosphoric Oil.

Put one part of phosphorus into six of olive oil, and digest them over a sand heat. The phosphorus will dissolve. It must be kept well corked.

This oil has the property of being very luminous in the dark, and yet it has not sufficient heat to burn any thing. If rubbed on the face and hands, taking care to shut the eyes, the appearance is most hideously frightful; all the parts with which it has been rubbed appear to be covered with a very luminous lambent flame of a bluish colour, and the mouth and eyes appear in it as black spots. There is no danger attending this experiment. The light of it is sufficient to shew the hour of the night on a watch, by holding it close to the bottle when it is unstopped.

To make Phosphorated Lime.

Put a few grains of phosphorus into the bottom of a Florence flask, and fill it up with quick lime. Place it over a lamp till the phosphorus has sublimed, and is thoroughly mixed with the lime. If any of this lime be thrown out in the dark, it has the appearance of a shower of fire, but cannot burn any thing, as the quantity of phosphorus is too small to produce any sensible heat.

To make a Phosphoric Fire Bottle.

Take a very small phial, and put into it a bit of phosphorus as large as a pea, and fill up the bottle with lime. Fix an iron vessel, as a shovel, for instance, with common sand, and put it over the fire. Set the phial in this sand, having loosely stopped it with a cork. Stir about the ingredients with a wire, and mix them together, taking care that

the phosphorus does not catch fire by too great an access of air. Keep the bottle in the sand till the phosphorus is thoroughly incorporated with the lime, when it will be of a reddish yellow.

This bottle is extremely convenient for procuring an instantaneous light in the dark. For this purpose, nothing more is necessary than to uncork the bottle, and to introduce a brimstone match, stirring it about a little, by which it will catch fire and light.

The bottle must be always kept carefully corked, and opened as seldom as possible.

A more durable kind may be made by uniting together one part of sulphur with eight of phosphorus. When this is used, a match is introduced into it, and then rubbed upon a bit of cork.

To make Phosphuret of Lime.

Put half an ounce of phosphorus, cut into small bits, into a glass tube about a foot long, and half an inch in diameter, closed at one end. Fill up with quick lime grossly powdered, and stop the mouth of the tube loosely. Heat that part of the tube which contains the lime, over a chafing dish, till it be red hot; and then apply the heat of a lamp to the part containing the phosphorus, which will sublime, and mix with the lime. When cooled, the mixture will be a reddish mass.

If phosphuret of lime be dropped into water, air bubbles will be disengaged, which, on bursting at the top, will inflame with small explosions. They consist of phosphorated hydrogen gas.

To make Fulminating Powder.

Triturate in a warm mortar three parts by weight, of nitre, two of mild vegetable alkali (carbonate of potass), and one of flowers of sulphur. A few grains of this laid upon a knife, and held over the candle, first fuses, and then explodes with a loud report. A drachm of it put into a shovel, and held over the fire, makes a noise as loud as a cannon, and indents the shovel as if it had received a violent blow.

To make Fulminating Mercury.

Dissolve 100 grains of mercury with heat, in a measured ounce and a half of nitric acid. This solution being poured cold upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action. The precipitate is to be immediately collected on a filtre, well washed with distilled water, and cautiously dried in a heat not exceeding that of a water bath. The immediate washing of the powder is material, because it is liable to the re-action of the nitric acid; and while any of the acid adheres to it, it is very subject to the action of light. From 100 grains of mercury, about 120 or 130 of the powder are obtained.

This powder, struck on an anvil with a hammer, explodes with a stunning disagreeable report; and with such force as to indent both the hammer and the anvil. Three or four grains are as much as ought to be used for such experiments.

To make the Arbor Dianæ, or Tree of Diana.

Take half an ounce of fine silver, and two drachms of mercury, and dissolve them separately in a quantity of aquafortis, no longer than necessary. When the solutions are perfectly made, mix them together, and pour them into a pint of common water, and stir it about, that the whole may be well mixed. Keep this preparation in a bottle well corked. In a glass globe, or other vessel, put the quantity of a small nut of the amalgam of silver with mercury, and pour three or four ounces of the above liquor over it. After some hours there arise from the little globular amalgam small branches, that, by increasing, will form a beautiful kind of shrub, or tree of silver.

To make a Tree of Silver on Glass.

Put a few drops of the solution of silver in aquafortis on a piece of glass, and having formed a bit of copper or brass wire to represent a tree with its branches, but flat, so as to lie upon the glass, lay it in the liquid, and let it remain for an hour or two. A beautiful vegetation will be perceived all round the wire, which will nearly be covered by it. This may be preserved by washing it very carefully with water, and putting another glass over it.

To produce a Tree of Lead.

Dissolve an ounce of sugar of lead in a quart of clear water, and put it into a glass decanter or globe. Then suspend in the solution, near the top, a small piece of zinc of an irregular shape. Let it stand undisturbed for a day, and it will begin to shoot out into leaves, and apparently to vegetate. If left undisturbed for a few days, it will become extremely beautiful; but it must be moved with great caution.

It may appear to those unacquainted with chemistry, that the piece of zinc actually puts out leaves; but this is a mistake, for if the zinc be examined, it will be found nearly unaltered. This phenomenon is owing to the zinc having a greater attraction for oxygen than the lead has; consequently, it takes it from the oxyde of lead, which re-appears in its metallic state.

Arbor Martis, or Tree of Mars.

Dissolve iron filings in aquafortis moderately concentrated, till the acid is saturated; then add to it gradually a solution of fixed alkali, commonly called oil of tartar per deliquium. A strong effervescence will ensue, and the iron, instead of falling to the bottom of the vessel, will afterwards rise, so as to cover the sides, forming a multitude of ramifications heaped one upon the other, which will sometimes pass over the edge of the vessel, and extend themselves on the outside with all the appearance of a plant.

Changing Iron apparently into Copper.

Dissolve some blue vitriol (sulphate of copper) in water, and dip into the solution a piece of bright iron or steel; in a few seconds it may be taken out, when it will be apparently turned to copper. This is a deception; the iron is not changed into copper; it is only encrusted over with that metal, as may be easily seen by removing the copper by a file. The iron having a stronger attraction for sulphuric acid than copper, it

takes the acid from the latter, which is consequently precipitated. This process is used for obtaining the copper from waters near mines that contain a great quantity of that metal. Iron plates are put into them, which become incrusted with copper, which is scraped off.

To prepare the Precipitate of Cassius.

This beautiful purple colour is extremely useful to enamellers and glass stainers. To make it proceed as follows:

Dissolve some gold in aquaregia (nitro-muriatic acid), and also dissolve some pure tin in diluted aquaregia, and pour it into the solution of gold. A purple powder will be precipitated, which must be collected and washed in distilled water.

A method of Silvering Ivory.

Take a slip of ivory, immerse it in a weak solution of nitrate of silver, and let it remain in it till the ivory has acquired a bright yellow colour; then take it out of the solution, and immerse it in a tumbler of pure water, and expose it in the water to the rays of a very bright sun. After the ivory has been exposed to the sun's rays for about two or three hours, it becomes black; but on rubbing it a little, the black surface will become changed into one of silver. Although this coating of silver is extremely thin, yet if the ivory be well impregnated with the nitrate of silver, the solution will penetrate to a considerable depth; and as fast as the silver wears off from the surface of the ivory, the nitrate below being exposed to the light, is converted into silver and the ivory retains its metallic appearance.

To cover Ribbons with Gold by a Chemical Process.

Let ether stand over phosphorus for some weeks, and some of the phosphorus will be dissolved. Dissolve also some gold in aquaregia (nitro-muriatic acid). Dip the ribbon, first, into the nitro-muriatic solution, and then into the phosphorated ether, and it will be covered with a firm coating of gold.

The same effect may be produced by exposing the ribbon, after having dipped it into the solution of gold, to a current of phosphorated hydrogen gas for some days.

To prepare Aurum Musivum.

Aurum musivum is used by japanners, and for many varnished works, as snuff boxes, coaches, &c. When well managed, it has all the beautiful appearance of gold in powder.

To make it, amalgamate twelve parts of the purest tin with three parts of mercury. The amalgam must then be triturated in a stone mortar with seven parts of flowers of sulphur and three parts of sal-ammoniac. The mixture is then put into a matrass, and the whole is exposed to a gentle sand heat, until no more white fumes arise. When, upon this, the heat is somewhat raised, cinnabar sublimes, together with some oxygenated muriate of tin; while, at the same time, the remaining tin unites with the remaining sulphur, and forms the aurum musivum, exhibiting a golden yellow and flaky or scaley matter, of a metallic lustre.

The main point in this process is the proper regulation of the fire:

when this is too strong, the operation does not succeed; and instead of aurum musivum, common sulphuret of tin is obtained.

To make an Artificial Volcano.

For this curious experiment, which enables us to assign a very probable cause for volcanoes, we are indebted to Lemery.

Mix equal parts of pounded sulphur and iron filings, and having formed the whole into a paste with water, bury a quantity of it, forty or fifty pounds, for example, at about the depth of a foot below the surface of the earth. In ten or twelve hours afterwards, if the weather be warm, the earth will swell up and burst, and flames will issue out, which will enlarge the aperture, scattering around a yellow and blackish dust.

It is not impossible, that what is here seen in miniature takes place on a grand scale in volcanoes; as it is well known that they always furnish abundance of sulphur, and also metallic substances.

To produce Artificial Lightning.

Provide a tin tube, that is much larger on one side than the other, and in which there are several holes. Fill this tube with resin, in powder, and when it is shook over the flame of a torch, it will produce a sudden corruscation, that strongly represents a flash of lightning. This is the manner in which lightning is produced at the theatres: it is not the flame itself that is to be seen, but its reflection only, as happens for the most part in nature.

It is in this manner that the flambeaux of the furies on the stage are constructed, except that, at the end of each of them, there is a match dipped in spirits of wine; by means of which it is only necessary to shake them, and they will produce a sudden and very considerable flame.

Method of cutting Glass, by Means of Heat.

Take a common wine glass, or any vessel you want cut, and having heated a poker in the fire till it is almost red hot, but not quite, apply it to the part where you wish the crack to begin; having held it upon the part for about a minute, remove the poker, and wet the place: the glass will immediately crack. Having now begun the crack, you may lead it in any direction, by merely drawing the hot poker in the direction you want. This is extremely useful in many chemical experiments, where you are in want of proper apparatus.

Glass tubes may be easily cut with a file.

A curious Method of forming Pictures by Nitrate of Silver.

It is well known that light has a powerful effect upon many of the metallic oxydes, causing them to turn black.

Mr. J. Wedgewood has availed of this property for copying paintings on glass, and making profiles of figures by means of nitrate of silver.

Cover white paper, or leather, with a solution of nitrate of silver, and place it behind a painting on glass, which is exposed to the rays of the sun. The rays which come through will blacken the paper; but the shades will be more or less deep, in proportion to the quantities of light transmitted through the different parts of the glass. Where the glass is transparent, and all the light comes through, the paper will be made quite black; where the glass is quite opaque, and does not trans-

mit any light, the paper will be quite white; and there will be degrees of intensity of the shadow of every variety between these.

This picture is not sensibly affected by the light of candles or lamps; but the day light destroys it very soon, causing all the paper to become black; nor have any means hitherto tried for preventing this been successful.

Besides the application of this property of nitrate of silver to copying the light and shadow of paintings on glass, it may be applied to some others. By means of it delineations may be made of all such objects as are partly opaque and partly transparent. The fibres of leaves, and the wings of insects, may be pretty accurately represented by it, by only making the solar rays pass through them, upon prepared leather or paper.

Professor Davy has found, that the images of small objects produced by means of the solar microscope, may be copied without difficulty on prepared paper. He found that the best proportion was one part of nitrate to about ten of water. This is sufficient to enable the paper to become tinged, without hurting its texture.

Artificial Fire-Works.

Artificial fire-works are of two kinds—those made of gunpowder, nitre, and other inflammable substances and filings of the metals, camphor, &c. and those produced by hydrogen or inflammable air.

Those made with gunpowder are well known, and are called rockets, fire-wheels, tourbillons, &c.

Of these, the most usual are rockets. They are made by ramming into strong cylindrical paper cases put into wooden moulds, like small hollow columns, powdered gunpowder, or the ingredients of which it is composed, viz. saltpetre, sulphur, and charcoal, very dry.

If you would represent a fiery rain falling from the rocket, mix among your charge a composition of powdered glass, filings of iron, and saw-dust; this shower is called the peacock's tail, on account of the various colours that appear in it. Camphor mixed with the charge, produces white or pale fire; resin a reddish colour, sulphur a blue, sal-ammoniac a green, antimony a reddish yellow, ivory shavings a silvery white, pitch a deep or dark coloured fire, and steel filings, beautiful corruscations and sparks.

Sticks are fastened to the rockets, by which they are projected into the air, after they have been lighted: the charge burning with great intensity at one end, acts upon the air, which, in its turn, re-acts upon the rocket, and causes it to ascend, on the same principle as a boat is put off by a man in it, who pushes against the shore with a boat-hook.

Fire-works by means of inflammable air are the most elegant; and being free from smell or smoke, may be exhibited in a room without any disagreeable effect.

The philosophical light has been already described under chemistry, when treating of hydrogen gas. By referring to what is there said, the principle of these fire-works will easily be understood. Small copper or tin tubes must be provided, of about a quarter of an inch in diameter; these tubes must be formed into the shapes required, and pierced with very small holes where a flame is wanted to appear; to these pieces must be attached large bladders, or air-tight bags, filled with hydrogen gas. There must also be a stop cock between the tubes and

the bladders, to open or close the communication. Having prepared every thing properly, open the stop cock, and press the bladders; the hydrogen will be forced out through the holes in the tubes, and by means of a taper, may be inflamed. A constant stream of fire may be kept up as long as there is any air in the bladders.

Upon this principle were constructed the beautiful fire-works lately exhibited in London by Mr. Cartwright.

Of Artificial Grottoes and Shell-Work.

The idea of artificial grottoes is almost always wrongly conceived. Those who construct them frequently imagine that they are imitating nature, while at the same time every thing they do is directly the reverse. Who ever saw a natural grotto or cavern, covered in the inside with beautiful shells stuck all over it, intermixed with pieces of coral, looking-glass, and every species of shewy ornament? And those who aim at making a more sober species of grotto, by introducing only rough masses of stone to imitate natural rocks, and covering the whole with moss, weeds, &c. always fail in their attempts to imitate nature. To say the truth, the difficulties in this species of imitation are by far greater than most people have any idea of. To succeed, the abilities not only of the naturalist, but also those of the painter and the architect, are absolutely necessary. No person ignorant of these sciences can properly conceive the design, and distribute in an easy and natural manner the various materials. Nothing is more difficult than to imitate nature, and a failure in the attempt always disgusts.

There is another idea, however, that may be entertained with regard to artificial grottoes, which is, that they need not represent natural caverns, but the supposed productions of enchantment or magic. In this light, most of the incongruities will disappear, and every possible licence may be given for the display of imagination and taste. Nothing is supposed to be impossible to magical power: therefore every species of natural or artificial productions may be combined together, and every thing introduced that may excite astonishment and surprise. There is no necessity either for imitating the appearance of natural grottoes, but every species of regularity and irregularity may be licensed. The sciences of architecture and mechanics may thus lend their aid in the construction of places, where mere nature is not the object of imitation, but where every thing may be employed that can have a powerful effect upon the imagination.

Shell-work, corals, statues, fountains, streams of water, paintings, curious musical pieces of mechanism; in short, every thing extraordinary, may be introduced with great success; and in this art there is an ample field for the display of taste.

The external of a grotto is the part where the least attempt at ornament should be made. It is best made to resemble some hermitage constructed of roots of trees, or some similar kind of structure; but no attempt should ever be made here to imitate a natural cavern, except, indeed, the situation should be peculiarly happy for this purpose.

A cement for fixing large shell-work and stones may be prepared as follows: Melt together a quantity of resin, pitch, and bees-wax, and add to it powdered marble or freestone, and a little sulphur. Any of the finer cements mentioned under the article cements, may be used for delicate purposes.

We cannot help mentioning here, that the taste of those who spend their time in making small pieces of shell-work to put into frames, must be sadly perverted; and it is a great pity to see so much ingenuity and patience misapplied. The thing produced can never affect the mind with any refined sensation; and it is a mere childish toy, the construction of which is a very unfit employment for the leisure hours of one who is possessed of natural powers capable of cultivation.

We do not consider large grotto work quite in the same light; but it requires a degree of skill that very few are possessed of, to make them interesting.

To make Artificial Coral for Grottoes.

To two drachms of fine vermilion add one ounce of clear resin, and melt them together. Having your branches or twigs peeled and dried, paint them over with this mixture while hot. The black thorn is the best branch for it. Hold them over a gentle fire, turning them round till they are perfectly covered and smooth. You may make white coral with white lead, and black with lamp-black.

To take Impressions from Leaves.

Take green leaves of trees or flowers, and lay them between the leaves of a book till they are dry. Then mix up some lamp-black with drying oil, and make a small dabber of some cotton wrapped up in a piece of soft leather. Put your colour upon a tile, and take some on your dabber. Laying the dried leaf flat upon a table, dab it very gently with the oil colour, till the veins of the leaf are covered; but you must be careful not to dab it so hard as to force the colour between the veins. Moisten a piece of paper, or rather have a piece lying between several sheets of moistened paper for several hours, and lay this over the leaf which has been blackened. Press it gently down, and then subject it to the action of a press, or lay a heavy weight on it, and press it down very hard. By this means you obtain a very beautiful impression of the leaf and all the veins; even the minutest will be represented in a more perfect manner than they could be drawn with the greatest care. These impressions may also be coloured in the same manner as prints.

A method of making Pictures of Birds, by means of their own Feathers.

Get a thin board or pannel of deal, or wainscot, well seasoned, that it may not warp. Paste white paper over it, and let it dry. Take any bird that you would wish to represent, and draw its outline on the paper in the attitude you desire, and of the full size, adding what landscape, back-ground, &c. you wish. This outline, so drawn, is afterwards to be filled up with the feathers from the bird, placing each feather in that part of the drawing corresponding to the part of the bird it was taken from.

To do this, cover the representation with several coats of strong gum water, letting it dry between each coat till it is of the thickness of a shilling. When your ground is thus prepared, take the feathers off from the bird, beginning at the tail or points of the wings, as you must work upwards towards the head. These feathers must be prepared by cutting off all the downy part; and the larger feathers must have the insides of their shafts pared off, to make them lie flat. To lay them on, make use of a pair of small pliers to hold them by; and moistening

the gummed ground with water, place each feather in its natural and proper situation. Keep each feather down, by putting a small leaden weight upon it, till you have another prepared to lay on. You must be careful not to let the gum come through the feathers, as it smears them, and sticking to the bottoms of the weights, will be apt to pull the feathers off. When you have put on all the feathers, you must cut a piece of round paper, and colour it like the eye, which you may stick in its place; but the best way is to get small eyes made of glass. The bill, legs, and feet, must be drawn and coloured from nature. When it is finished and adjusted to your mind, lay a sheet of paper upon it, and upon that a heavy weight to press it; which must remain till the whole is quite dry.

To take the Impression of any Butterfly in all its Colours.

Having taken a butterfly, kill it without spoiling its wings, which contrive to spread out as regularly as possible in a flying position; then, with a small brush or pencil, take a piece of white paper; wash part of it with gum water, a little thicker than ordinary, so that it may easily dry; afterwards, laying your butterfly on the paper, cut off the body close to the wings, and throwing it away, lay the paper on a smooth board, with the fly upwards; and laying another paper over that, put the whole preparation into a screw press, and screw it down very hard, or otherwise press it, letting it remain under that pressure for half an hour. Afterwards take off the wings of the butterfly, and you will find a perfect impression of them, with all their various colours marked distinctly, remaining on the paper. When this is done, draw between the wings of your impression the body of the butterfly, and colour it after the insect itself.

To lay Mezzotinto Prints upon Glass.

Take what mezzotinto prints you please; cut off the margin, and lay it flat in a dish of clear hot water; let it remain on the surface till it sinks. When you take it out, be careful not to break it, and press it betwixt clean cloths or papers, so that no water may appear on the surface, but the prints be quite damp: then lay it, face uppermost, on a flat table; have ready a plate of pure crown glass, free from all spots or scratches; lay some Venice turpentine all over one side of it with a soft brush, and hold it to the fire a little, to make it run quite equal and thin; then let it fall gently on the print. Press it down, that the turpentine may stick to the print; and also press the print with your fingers, from the middle to the edges of the glass, so that no blisters may remain. Wet your print now with a soft cloth, and rub it gently with your finger, and the paper will peel off, leaving only the impression upon the glass. When it is dry, wet it over with oil of turpentine till it is transparent, and set it by to dry, when it will be fit for painting. The colours used for painting in this manner are the usual oil colours, and there is nothing in the process particular.

To make Artificial Pearls.

Take the blay or bleak fish, which is very common in the rivers near London, and scrape off the fine silvery scales from the belly. Wash and rub these in water. Then suffer this water to settle, and a sediment will be found of an oily consistence. A little of this is to be drop-

ped into a hollow glass bead of a bluish tint, and shaken about, so as to cover all the internal surface. After this, the bead is filled up with melted white wax, to give it solidity and weight.

To prepare the Nuremberg Powder of variegated Colour.

Mix together clean filings of copper, brass, iron, steel, and other metals. Put each of them separately into an iron vessel, and heat them till they change colour. The degree of heat can only be regulated by trial. Take these to a good flatting mill, furnished with a funnel at top, and pass these filings through it, and you will procure a most beautiful sparkling powder of all sorts of lively colours.

To make very beautiful Artificial Petrefactions.

Put into a retort a quantity of pounded fluor spar and a few bits of broken glass, and pour upon them some súlphuric acid; fluoric acid gas will be disengaged, holding silex in solution. The substances to be made to resemble petrefactions, as lizards, frogs, branches of trees, birds' nests, &c. must now be moistened with water, and placed in a vessel connected with the neck of the retort. The fluoric acid gas will be absorbed by the moisture adhering to the substances, and the silex will be precipitated upon them like a sort of hoar-frost, which will have a very beautiful appearance, and is very durable.

New method of making Cast-Steel.

This method has been lately invented in France. It is as follows:—Take small pieces of iron, and place them in a crucible, with a mixture of chalk or lime-stone and the earth of Hessian crucibles. Six parts of chalk and six of this earth must be employed for twenty parts of the iron. The matters are to be so disposed, that, after fusion, the iron must be completely covered by them, to prevent it from coming into contact with the external air. The mixture is then to be gradually heated, and at last exposed to a heat capable of melting iron. If the fire be well kept up, an hour will generally be sufficient to convert two pounds of iron into excellent and exceedingly hard steel, capable of being forged; an advantage not possessed by steel made in the usual manner.

Method of distinguishing Iron from Steel.

Drop a little weak aquafortis on the metal; let it remain for a few minutes, and then wash it off with water. If it is steel, the spot will be black; but if iron, the spot will be whitish grey.

A Test for discoveeing the presence of Lead, Copper, &c. in Wines.

Lead and copper being sometimes used to amend the taste of wines, and these metals being of a very poisonous quality, a test that shall detect this is of great value. The following test is the discovery of Mr. Hanhemann, and is found to answer perfectly.

Equal parts of oyster shells and crude sulphur are to be kept in a white heat for a quarter of an hour, and, when cold, this is to be mixed with an equal quantity of acidulous tartrite of potass, and put into a strong bottle with common water for an hour, and then decanted into bottles holding an ounce each, with twenty drops of muriatic acid in each.

This liquor precipitates the least quantities of lead, copper, &c. from wines, in very sensible black precipitate.

To make Pearl-White.

Put some good aquafortis into a Florence flask, and gradually add to it bismuth broken into small pieces, till no more dissolves; then let the solution remain till it is transparent. Add to this some water, and a white precipitate will be formed, which is to be washed and dried This is white oxyde of bismuth, commonly termed magistery of bismuth, or pearl-white.

This is used as a cosmetic, and is sold by the perfumers; but it very much impairs the skin, blackening it by degrees, so that once used, it must be continued; and it is also to be feared, that it has besides deleterious effects upon the constitution.

To procure Animalculæ for the Microscope.

The surface of infused liquors is generally covered with a thin pellicle, which is easily broken, but acquires thickness by standing; the greatest number of animalculæ are generally to be found in this superficial film.

To make an infusion of Pepper.—Cover the bottom of an open jar, about half an inch thick, with common black pepper bruised; pour as much soft water in the vessel as will rise about an inch above the pepper. The pepper and water are then to be well shaken together; after which they must not be stirred, but be left exposed to the air for a few days, when a thin pellicle will be formed on the surface of the water, containing millions of animalculæ.

To procure the eels in paste, boil a little flour and water till it becomes of a moderate consistence; expose it to the air in an open vessel, and beat it together from time to time, to prevent the surface from growing hard or mouldy: after a few days, especially in summer time, it will turn sour; then, if it be examined with attention, you will find myriads of eels on the surface. Apply them to the microscope on a slip of flat glass, first putting on it a drop of water, taken up by the head of a pin, for them to swim in.

A very useful Method of breaking up Logs of Wood.

The usual way of breaking up logs of wood for the purposes of fuel, is by axes, and driving wedges in. This, particularly in roots of trees, is very laborious. It is also sometimes done by gunpowder, in the same way as stones and rocks are blasted; but this is very troublesome, as the plug is often driven out. A better method of performing this operation has lately been invented. A hole is bored with an augre, and a charge of powder introduced. An iron screw, with a good thread, having a hole bored through its axis, is then introduced into the hole, and turned till it come near to the powder. While the screw is putting in, a wire is kept in the hole through its axis, but it is afterwards drawn out, and a piece of twine dipped in a solution of nitre is put into its place. This quick match is set fire to, and by its slow burning, affords time for the operator to retire before it sets fire to the gunpowder.

By this means, any roots or old stumps of trees may be easily broken up.

A process for purifying Fish Oil.

Take a gallon of crude stinking oil, and put to it a pint of water poured off from two ounces of lime slaked in the air; stir the mixture up several times for the first twenty-four hours; then let stand a day, and the lime water will sink below the oil, which must be carefully separated from it.

Another Method for purifying it more completely.

Take a gallon of crude stinking oil, and mix with it a quarter of an ounce of powdered chalk, a quarter of an ounce of lime, slaked in the air, and half a pint of water; stir them together; and when they have stood some hours, add a pint of water, and two ounces of pearl-ashes, and place the mixture over a fire that will just keep it simmering, till the oil appears of a light amber colour, and has lost all smell, except a hot, greasy, soap-like scent. Then superadd half a pint of water in which one ounce of salt has been dissolved, and having boiled it half an hour, pour the mixture into a proper vessel, and let it stand for some days, till the oil and water separate.

If this operation be repeated several times, diminishing each time the quantity of ingredients one half, the oil may be brought to a very light colour, and rendered equally sweet with the common spermaceti oil.

Oil purified in this manner is found to burn much better, and to answer better the purposes of the woollen manufacture. If an oil be wanted thicker and more unctuous, this may be rendered so by the addition of tallow or fat.

Process for Preserving the Canvas in Oil Paintings, and repairing Defects.

1*st*, Separate the canvass from the pannel, or straining frame, and lay it on a smooth table, with the painting downwards, and nail it securely.

2*d*, Take a piece of tinfoil, larger than the canvass, place it on a very smooth table, and make the tinfoil as smooth as possible with your hand. Then melt some Salisbury glue, in the same manner as for cabinet-makers' use.

3*d*, Warm the tinfoil before the fire, and lay it again on the table, then wash it over with the glue, and place it on the back of the canvas secured as above, as quick as possible; smooth it perfectly with the hand, and let it remain in a warm room to dry.

4*th*, To repair the cracks of the canvass, in an old oil painting, lay it on a very smooth table, the subject downwards; then, with a brush or fine linen, cover the canvass with some melted white wax, and, with a warm flat smoothing iron, rub over the wax, and press it hard, which will draw the colours up to the canvass.

5*th*, To varnish the painting, clean the picture well, take some white wax, and spirits of turpentine, with a small quantity of linseed oil and sugar of lead; melt them over the fire, dip a fine linen rag therein, with which wash your painting; then, with a fine linen rag, rub over the varnish till it begins to be polished; let it remain till next day, and then rub it over with a fine waxed cloth, and afterwards with a soft linen cloth, using them alternately, by which means the painting will receive a very fine polish.

By the above means, the cracks and small holes in old paintings may be closed and repaired, and a coat of tinfoil may be afterwards glued on the back of the canvass, as above mentioned.

A foot square of the tinfoil costs about sixpence; when wanted of a larger size it will cost considerably more in proportion. It may be procured in sheets of three or four feet if wanted.

Seeds.—An Easy Method of discovering whether or not Seeds are sufficiently ripe.

Seeds, when not sufficiently ripe, will swim, but when arrived at full maturity, they will be found uniformly to fall to the bottom; a fact that is said to hold equally true of all seeds, from the cocoa nut to the orchis.

On preserving Seeds of Plants in a State fit for Vegetation.

Seeds of plants may be preserved, for many months at least, by causing them to be packed, either in husks, pods, &c. in absorbent paper, with raisins or brown moist sugar; or a good way, practised by gardeners, is to wrap the seed in brown paper or cartridge paper, pasted down, and then varnished over.

To facilitate the Growth of Foreign Seeds.

Mr. Humbolt has found, that seeds, which do not commonly germinate in our climate, or in our hot-houses, and which of course we cannot raise for our gardens, or hope to naturalize in our fields, become capable of germinating, when immersed for some days in a weak oxygenised muriatic acid. This interesting discovery has already turned to advantage in several botanic gardens.

Management of Garden Borders.—To plant and make Edgings.

Edgings of daisies, thrift, violets, gentianella, &c. should be planted in February; but those of box succeed better if planted in April or August.

New edgings should be planted rather closely, that they may have an immediate effect; and, in repairing old ones, plant very close, that the whole may appear the more uniform. Some plant these, in either case, with the dibble, but it is better to do this with the spade; cutting out by the line, a drill, or furrow, perpendicular on the side next the border, and to a depth suitable to the size of the roots to be laid; placing them against the perpendicular side, and spreading out their fibres sideways; exposing them to the air as short a time as possible.

How to cut Box Edgings.

Box edgings should be cut about the beginning of April, or in the end of July. They should, however, be cut once a year, and should be kept two inches in breadth at bottom; being tapered up to a thin edge at top; for nothing looks so ill as a large bushy edging, especially to a narrow walk. The use of edging is to separate the earth from the gravel, and the larger they are allowed to grow, the less effectual they become; getting the more open below, as they advance in height. Such also harbour snails, and other troublesome vermin.

A sure Method of curing Gravel Walks.

Three parts pond water to one of brine, from the salting-tub in a family, poured with a watering pot upon gravel walks, will not only kill the moss upon them, but drive away the worms which make so many holes in them, and also prevent weeds springing up. This a gentleman has lately tried, who has several gravel walks in a grove near his house. Since he moistened his walks with brine, which is now four years ago, they are incommoded neither by moss, weeds, or worms. Every autumn he causes them to be well watered with the brine and pond water, during a whole week, to prevent moss, and a week in the spring, to guard against weeds and worms, besides giving them a sprinkling every now and then in summer season, when they seem to want it.

Culture and Management of Flowers—Proper Method of laying Carnations.

In summer, towards the latter end of June, or any time in July, or beginning of August, when the shoots of the year are advanced to a proper growth, being from four, five, or six, to seven or eight inches long, which are to be laid as they grow on the plants, and to remain affixed thereto till rooted in the ground.

Thus far observed; begin the work by first clearing away all weeds about the plants, and loosen the earth a little around them, and if the surface is low, add some mould thereto, sufficient to raise it high enough to receive the layers easily; then begin the laying the shoots one by one; strip off the lower leaves so as to have some inches of a clear shoot below; and trim the top leaves shorter and even, and then slit or gash the shoot on the under side; in doing which, fix on a joint about the middle of the shoot underneath, and with your sharp knife cut half through the joint, and slanting upwards, so as to slit the shoot up the middle half an inch, or but little more; which done, directly lay it, by bending it down to the earth with the gash or slit part open, making an opening in the earth, and peg it down with one or two of the small-hooked sticks, and earth over the body of the layer an inch or two deep, still keeping the slit open, and the top raised gently upright, pressing the earth moderately upon them; and in this manner proceed with laying all the shoots on each plant; and when all are laid give a gentle watering to settle the earth close about the layers, and repeat it frequently in dry weather.

They will soon emit roots at the gash or slit part, generally at the bottom of the tongue, and in five or six weeks will often be rooted fit for separating and planting off from the parent, so that when they have been about five, six, or seven weeks laid, you will examine the progress they have made in rooting, by opening the earth gently about some of the layers; and as soon as they appear to be tolerably rooted, let them be cut off from the old plant with a sharp knife, in order to be timely planted out in nursery beds, that they may root more abundantly, and get due strength before winter; observing, in cutting them off from the mother plant, to open the ground so as to take them up with all the roots they have made, and cut them clean off beyond the gash; afterwards trim off any naked woody part or bottom, but preserve all the roots, and trim the long tops a little, then plant them in nursery rows,

six inches asunder, or you may prick some in small pots, one layer in each, giving water directly at planting, and repeat it often in dry weather till they take good root, and grow freely, keeping them clean from weeds.

Those in the nursery beds will, by October, be good strong plants. The choicest sorts may then be planted in pots, to move under occasional shelter in time of severe frost, and for which purpose, either use small pots (32) to contain them all winter, or plant them in large pots (24 or 16) to remain to flower, observing to take them up out of the nursery beds for potting, &c. with a garden trowel, each layer with a good ball of earth about the roots; and having the pots ready, placing a shell over the holes at bottom, and put some good light rich earth therein; plant one layer with its ball about the roots entire, in each pot, fill up with more earth, and give some water; you may also at the same time plant some of the more ordinary or common sorts into flower-borders or beds, to stand the full weather all the year, but the choicer sorts in the pots, may, in November, be placed close together, either in a garden-frame, to have occasional protection of the glasses, or mats, in severe frost, and have the full air in all open weather and mild days, or may be plunged in a raised bed of any dry compost, raised some inches above the common level, and arched over with hoop arches, in order to be protected with occasional covering of garden mats when hard frosts prevail; but in either method be sure to expose them fully in all open weather, as aforesaid.

In the spring, such as have remained all winter in small pots, should, in February or early in March, be turned out with the ball of earth about the root, and planted into larger pots, to remain for flowering, giving proper waterings; and those which were potted at once into larger pots in autumn, should now have the earth stirred at top, taking out some, and filling up with fresh good earth, and give a little water.

The layers planted in the common borders of the pleasure and flower garden require no other care than keeping them clean from weeds, and tying up the flower stalks to sticks when they are advanced long enough to require support.

Plants watered by being placed in Dishes, improper.

The practice of placing flats or saucers under plants, and feeding them by the roots, that is, pouring the water continually into these dishes, and never on the earth at top, is highly improper. The water should always be poured on the surface of the earth, that it may filtre completely through it, to the benefit and refreshment of the fibres.

When to plant Annual and Perennial Flowers.

Many kinds of annuals and perennials, sown in March and the beginning of April, will be fit for transplanting about the end of May, and may either be planted in patches about borders, or in beds, as fancy shall direct. Of these, the kinds improved by transplanting are, amaranthuses, China asters, columbines, French and African marigolds, fox-gloves, holly hocks, India pinks, love-lies-a-bleeding, mallows, mignionette, prince's feather, scabious, stocks, sun-flowers, sweet-williams, wall-flowers, and others. They should be planted out in a showery time, if possible, or otherwise be frequently watered, till they have struck root.

To Remove Herbs and Flowers in the Summer.

If you have occasion to transplant in the summer season, let it be in the evening after the heat is past, plant and water the same immediately, and there will be no danger from the heat next day; but be careful, in digging up the earth, you do not break any of the young shoots, as the sap will exude out of the same to the great danger of the plants.

Method of growing Flowers and Fruits during Winter.

In order to produce this effect, the trees or shrubs being taken up in the spring, at the time when they are about to bud, with some of their own soil carefully preserved among the roots, must be placed upright in a cellar till Michaelmas; when, with the addition of fresh earth, they are to be put into proper tubs or vessels, and placed in a stove or hot-house, where they must every morning be moistened or refreshed with a solution of half an ounce of sal-ammoniac in a pint of rain water. Thus, in the month of February, fruits or roses will appear; and, with respect to flowers in general, if they are sown in pots at or before Michaelmas, and watered in a similar manner, they will blow at Christmas.

To preserve delicate young Shoots of Flowers from Slugs and Earwigs.

Earwigs and slugs are fond of the points of the young shoots of carnations and pinks, and are very troublesome in places where they abound. To prevent them from getting to the fine stage plants, or supports of the stage, they are sometimes insulated in water, being set in cisterns or pans. If a pencil, dipt in oil, was drawn round the bottom of the pots once in two days, neither of these insects nor ants would attempt them. Few insects can endure oil. The smallest drop of it is instantly fatal to many kinds.

Virtues of the Sun-Flower.

The cultivation of the annual sun-flower is recommended to the notice of the public, as possessing the advantages of furnishing abundance of agreeable fodder for cattle in their leaves. When in flower, bees flock to them from all quarters to gather honey. The seed is valuable in feeding sheep, pigs, and other animals; it produces a striking effect in poultry, as occasioning them to lay more eggs, and it yields a large quantity of excellent oil, by pressure; the dry stalks burn well, the ashes affording a considerable quantity of alkali.

To preserve Flower Seeds.

Those who are curious about saving flower seeds, must attend to them in the month of August. Many kinds will begin to ripen apace, and should be carefully sticked and supported to prevent them from being shaken by high winds, and so partly lost. Others should be defended from much wet; such as asters, marigolds, and generally those of the class Syngenesia; as from the construction of their flowers they are apt to rot, and the seeds to mould, in bad seasons. Whenever they are thought ripe, or indeed any others, in wet weather, they should be removed to an airy shed or loft, gradually dried, and rubbed or beat out at conveniency.

Culture and Treatment of Fruit Trees and Shrubs.—To prevent Blossom and Fruit Trees from being damaged by early Spring Frost.

If a rope (a hempen one it is presumed) be intermixed among the branches of a fruit-tree in blossom, and the end of it brought down, so as to terminate in a bucket of water, and should a slight frost take place in the night-time, in that case the tree will not be affected by the frost; but a film of ice, of considerable thickness, will be formed on the surface of the bucket in which the rope's end is immersed, although it has often happened that another bucket of water, placed beside it for the sake of experiment, has had no ice at all upon it.

Chinese Mode of propagating Fruit Trees.

The ingenious people of China have a common method of propagating several kinds of fruit trees, which of late years has been practised with success in Bengal. The method is simply this :—They strip a ring of bark, about an inch in width, from a bearing branch, surround the place with a ball of fat earth, or loam, bound fast to the branch with a piece of matting: over this they suspend a pot or horn, with water, having a small hole in the bottom just sufficient to let the water drop, in order to keep the earth constantly moist. The branch throws new roots into the earth just above the place where the ring of bark was stripped off. The operation is performed in the spring, and the branch is sawn off and put into the ground at the fall of the leaf. The following year it will bear fruit.

To improve Fruit Trees by Attention to the Colour of the Soil.

The colour, and also the quality of soils, have an effect on the colour and flavour of fruits—even on the colour of many flowers. The effects of the colour of soils on that of fruits are most perceptible on the delicate kinds, such as grapes, peaches, &c. but to a nice observer it extends in a greater or less degree to all fruits. For instance, if two black Hamburgh grapes, made from the cuttings of the same plant, shall be planted, the one in a dry hazely loam, and the other in a moist black earth, the fruit of the one will be brown, or of a grizly colour, and the other very dark red or black; and the grape will be more juicy, though better in flavour, than the other grown in a drier soil.

To increase the Growth in Trees.

It may be depended upon as a fact, that by occasionally washing the stems of trees, their growth will be greatly increased: for several recent experiments have proved that all the ingredients of vegetation united, which are received from the roots, stem, branches, and leaves, of a mossy and dirty tree, do not produce half the increase either in wood or fruit, that another gains whose stem is clean. It is clearly obvious that proper nourishment cannot be received from rain, for the dirty stem will retain the moisture longer than when clean, and the moss and dirt will absorb the finest parts of the dew, and likewise act as a screen, by depriving the tree of that share of sun and air which it requires.

A common scrubbing brush and clean water is all that is necessary, only care must be observed not to injure the bark.

To prevent Hares and Rabbits from barking young Plantations.

Hares, rabbits, and rats have a natural antipathy to tar; but tar, though fluid, contracts, when exposed to the sun and air for a time, a great dryness and a very binding quality; and if applied to trees in its natural state, will occasion them to be bark bound. To remove this difficulty, tar is of so strong a savour, that a small quantity mixed with other things, in their nature open and loose, will give the whole mixture such a degree of its own taste and smell, as will prevent hares, &c. touching what it is applied to.

Take any quantity of tar, and six or seven times as much grease, stirring and mixing them well together: with this composition brush the stems of young trees, as high as hares, &c. can reach; and it will effectually prevent their being barked.

Bad effects of Iron Nails, &c. on Fruit Trees, or mischievous Effects of Iron Nails in Conjunction with Branches of Fruit Trees.

It often happens that some of the limbs of fruit trees, trained against a wall, are blighted and die, while others remain in a healthy and flourishing state. This has been hitherto erroneously attributed to the effects of lightning; but, from closer observation, and from several experiments, it has been found to arise from the corroding effects of the rust of the nails and cramps with which trees in this situation are fastened. To avoid this inconvenience, therefore, it requires only to be careful in preventing the iron from coming in contact with the bark of the trees.

To destroy Moss on Trees.

Remove it with a hard scrubbing brush in February and March, and wash the trees with cow dung, urine, and soap-suds.

Necessity of taking off superfluous Suckers from Shrubs.

Many flowering shrubs put out strong suckers from the root, such as lilacs, syringa, and some of the kinds of roses, which take greatly from the strength of the mother plant; and which, if not wanted for the purpose of planting next season, should be twisted off, or otherwise destroyed.

To cure the Disease in Apple Trees.

Brush off the white down, clear off the red stain underneath it, and anoint the places infected with a liquid mixture of train oil and Scotch snuff.

To cure the Canker in Trees.

Cut them off to the quick, and apply a piece of sound bark from any other tree, and bind it on with a flannel roller. Cut off the canker, and a new shoot will grow strong, but in a year or two you will find it cankered.

A Method of curing Fruit Trees infected with an Easterly Blight.

Where valuable fruit trees are infected with this blight, they may, with little trouble and expence, be in a short time cured, by fumigating them with brimstone strewed on light charcoal; this effectually kills them; but the workman must observe to get to windward of the

trees, as the fumes, both of brimstone and charcoal, are very offensive and pernicious.

Mr. Miller recommends washing and sprinkling the blighted trees from time to time, with common water (that is, such as hath not had any thing steeped in it), and the sooner that is performed (whenever we apprehend danger) the better; and if the young and tender shoots seem to be much infected, wash them with a woollen cloth so as to clear them, if possible, from all glutinous matter, that their respiration and perspiration may not be obstructed, and if some broad flat pans, or tubs, are placed near the trees, it will keep their tender parts in a ductile state, and greatly keep them; but whenever this operation of washing the trees is performed, it should be early in the day, that the moisture may be exhaled before the cold of the night comes on, especially if the nights are frosty, nor should it be done when the sun shines very hot upon the wall, which would be subject to scorch up the tender blossom.

Experienced Method of healing Wounds in Trees.

This method consists in making a varnish of common linseed oil, rendered very drying, by boiling it for the space of an hour, with an ounce of litharge to each pound of oil, mixed with calcined bones, pulverized and sifted, to the consistence of an almost liquid paste. With this paste the wounds of trees are to be covered, by means of a brush, after the bark and other substance have been pared, so as to render the whole as smooth and even as possible. The varnish must be applied in dry weather, in order that it may attach itself properly.

Composition for healing Wounds in Trees.

Take of dry pounded chalk, three measures; and of common vegetable tar, one measure; mix them thoroughly, and boil them, with a low heat, till the composition becomes of the consistency of bees-wax; it may be preserved for use in this state for any length of time. If chalk cannot conveniently be got, dry brick-dust may be substituted.

Application.—After the broken or decayed limb has been sawed off, the whole of the saw cut must be very carefully pared away, and the rough edges of the bark, in particular, must be made quite smooth: the doing of this properly is of great consequence; then lay on the above composition hot, about the thickness of half-a-crown, over the wounded place, and over the edges of the surrounding bark; it should be spread with a hot trowel.

To prune Wall Fruit.

Cut off all fresh shoots, however fair they may appear to the eye, that will not, without much bending, be well placed to the wall; for if any branch happen to be twisted or bruised in the bending or turning (which you may not easily perceive), although it may grow and prosper for the present, yet it will decay in time, and the sap or gum will issue from that place.

To prune Vines to Advantage.

In pruning vines, leave some new branches every year, and take away (if too many) some of the old, which will be of great advantage to the tree, and much increase the quantity of fruit.

When you trim your vine, leave two knots, and cut them off the next time; for, usually, the two buds yield a bunch of grapes. Vines, thus pruned, have been known to bear abundantly, whereas others that have been cut close to please the eye, have been almost barren of fruit.

The most proper Time when Leaves of Trees ought to be collected for pharmaceutical and economical Purposes.

It is at that period when the plant is in full flower that the leaves possess their full virtue. They drop when their particular life has terminated.

Culture and Management of Garden Crops.—To propagate Herbs, by Slips and Cuttings.

Many kinds of pot-herbs may, in July, be propagated by cuttings or slips, which may be planted out to nurse on a shady border for a few weeks, or till they have struck root, and may then be planted out where they are to remain. If made about the middle, or end of the month, they will be ready for transplanting before the end of August, and in that case will be well established before the winter.

The kinds are marjoram, mint, sage, savory, sorrel, tansy, tarragons, and thyme.

New Method of rendering Asparagus more productive, and of producing it in every Month in the Year.

The flowers of asparagus are found, on a strict examination, to be diæcious, although arranged by Linnæus, and other botanists, as hermaphrodite.

Those individuals which bear berries have abortive stamina, and those which have perfect stamina are destitute of pistils, or at leest have only abortive ones.

The male plants throw up a far greater quantity of shoots than the female ones, although not quite equal to them in size.

In the formation, therefore, of beds, the male plants only should be selected, which may easily be done by not planting them from the seed bed until they have flowered.

When the plants are one year old, transplant them into the other beds, at six inches distance; let them remain there until they flower, which will be in most of them, in the second year; put a small stick to each male plant, to mark them; and pull up the females, unless you choose to make a small plantation with some of them, to prove the truth of the experiment.

As asparagus is esteemed one of the greatest delicacies which the garden affords, no person fond of it should be unacquainted with the method of producing it in every month of the year.

Towards the end of July, especially if it be rainy weather, cut down the stalks of the asparagus, fork up the beds and rake them smooth. If it be dry, water them with the draining of a dunghill; but, instead of leaving them round, leave them rather flat or hollow in the middle, the better to retain the water or rain. In about twelve or fourteen days the asparagus will begin to appear, and, if it be dry weather, continue watering once or twice a week.

By this method you may cut asparagus till about the end of Sep-

tember, at which time the hot beds will succeed this; so that by making five or six hot beds during the winter, you may have a regular succession of it every month of the year.

Some persons will object to cutting the same beds twice a year: to obviate this objection, leave two or three beds uncut in spring, and make a few more beds, if you choose to follow the practice.

Asparagus seed is very cheap; nor is it necessary to use so much as was formerly used in making the beds. It is better to apply a little rotten dung on the tops of the beds, and to sow some seed every year, that you may have plenty of plants for forcing and making new beds. Be not too fond of continuing the old ones, when you perceive they begin to fail, but make new ones, and force the old roots.

To raise Capsicums, and make Cayenne Pepper.

Cayenne pepper is a spice used in most families, and often cultivated in the gardens for ornament, without either gentlemen or gardeners knowing that they have so valuable a spice in their possession; for the usual price is a shilling an ounce, and even then it is not much dearer than black, as it will go about four times as far.

This pepper originally came from Cayenne, in South America (and other warm countries), from whence it took its name, but is now so naturalized to this climate as to be raised on a common hot bed in spring.

It is produced from the capsicum, which is raised for ornament, with many other annual flowers, or for pickling the green pods, and is the seed and pod when ripe.

In March or April, procure some pods of any of the sorts of capsicums, as there are many varieties of them of different shapes; take out the seeds, and sow them on a hot bed, not too thick.

When they are about four inches high, prick them out on the hot bed, at six inches asunder; or put each into a small pot, or three into a large one, and keep them still under the glasses.

In June, when the weather is settled, plant them all in a warm situation, in rich earth, where they are to remain; some on the borders of the flower-garden, and some into larger pots, which you can shelter in bad weather.

New Method of raising Cucumbers.

From the best seed that can be got of the common prickly cucumber, raise plants on a moderate hot bed, not hurrying them too much in their growth. In May, when the danger of the frost is nearly over, familiarise the plants by degrees to the air, and towards the latter end of the month plant them in the open ground against a south wall. Take care not to give them too much water, as that will injure the fruit. When they have run up about five feet, they will send forth blossoms, and the fruit will begin to shew itself soon after. The flesh of cucumbers raised in this manner will be thicker and firmer, and the flavour vastly more delicious, than those raised from the same seed, but planted in the ordinary way, and the runners suffered to trail on the ground. Though a south wall, in most gardens, is too much appropriated to other things, to give room for cucumbers in general, yet in every garden a few plants may be so trained by way of rarity, and to save seed, which is found to be greatly improved by this method, so as to produce much better cucumbers in the common way of

raising them. One or two plants, so raised, will supply a sufficient quantity of seed for a large garden.

Laying a cucumber, or melon bed, with tiles, is also of particular service in improving the fruit, and giving it a proper flavour.

To prevent the irregular Growth of Melons.

It is well known that melons frequently, in certain situations, lose their circular form, and grow larger on one side than the other, and that those misshapen fruits are always bad. To remedy this, take a small forked stick, in proportion to the size of the melon, and thrust it into the ground as nearly as possible to the tail of the fruit, taking the precaution to lay a little moss between the two prongs, and suspend the melon to this fork. In a few days the melon will resume its form, when the fork may be removed, and the operation is finished. The quality of the fruit remains unchanged.

An easy Method of producing Mushrooms.

If the water wherein mushrooms have been steeped or washed be poured upon an old bed, or if the broken parts of mushrooms be strewed thereon, there will speedily arise great numbers.

To obtain a good Crop of Onions.

In order to obtain a good crop of onions, it is proper to sow at different seasons, viz. in light soils, in August, January, or early in February; and in heavy wet soils, in March, or early in April. Onions, however, should not be sown in January, unless the ground be in a dry state, which is not often the case at so early a period of the season; but if so, advantage should be taken of it.

The Advantage in sowing Peas in Circles instead of straight Rows.

It is a great error in those persons who sow the rows of tall growing peas close together. It is much better in all those sorts, which grow six or eight feet high, to have only one row, and then to leave a bed ten or twelve feet wide for onions, carrots, or any crops which do not grow tall.

The advantages which will be derived are, that the peas will not be drawn up so much, be stronger, will flower much nearer the ground, and in wet weather can be more easily gathered without wetting you.

But instead of sowing peas in straight rows, if you will form the ground into circles of three feet diameter, with a space of two feet between each circle, in a row thirty feet long, you will have six circles of peas, each nine feet; in all, fifty-four feet of peas instead of thirty, on the same extent of ground.

If you want more than one row of circles, leave a bed of ten or twelve feet before you begin another.

For the very tall sorts, four feet circles will afford more room for the roots to grow in, and care must be taken, by applying some tender twigs, or strings, to prevent the circles from joining each other.

This method is equally applicable for scarlet beans.

To raise Peas in Autumn, and to prevent Mice from eating them when sown.

The purple flowered peas are found to answer best for a late crop in autumn, as they are not so liable to be mildewed as many of the other sorts, and will continue flowering till the frost stops them.

Those peas may be sown in July, August, or so late as the first week in September, if sown in a warm sheltered situation, and in a soil inclining to sand.

Soak the peas in warm milk, and after you have drawn the drills, water them before you sow the peas: it is best to sow them towards the evening. If the autumn should prove very dry, they will require frequent watering.

When peas are sown before winter, or early in spring, they are very apt to be eaten by mice.

To prevent this, soak the peas for a day or two in train oil before you sow them, which will encourage their vegetation, and render them so obnoxious to the mice, that they will not eat them.

Method of cultivating Radishes for Salad, so as to have them ready at all Seasons of the Year.

Take seeds of the common radish, and lay them in rain water to steep for twenty-four hours; then put them quite wet, into a small linen bag, well tied at the mouth with a packthread. If you have steeped a large quantity of seeds, you may divide them into several bags. Then expose the bags in a place where they will receive the greatest heat of the sun, for about twenty-four hours, at the end of which time the seed will begin to grow, and you may then sow it in the usual manner, in earth well exposed to the heat of the sun. Prepare two small tubs to cover each other exactly. These may be easily provided, by sawing a small cask through the middle, and they will serve in winter; in summer one will be sufficient for each kind of earth that has been sown. As soon as you have sown your seeds you must cover them with your tub, and at the end of three days you will find radishes of the size and thickness of young lettuces, having at their extremities two small round leaves, rising from the earth, of a reddish colour. These radishes, cut or pulled up, will be excellent, if mixed with a salad, and they have a much more delicate taste than the common radishes which are eaten with salt.

By taking the following precautions you may have them in the winter, and even during the hardest frosts: After having steeped the seeds in warm water, and exposed them to the sun as already directed, or in a place sufficiently hot to make them shoot forth, warm the two tubs; fill one of them with earth well dunged; sow your seeds, thus prepared in one of them, and cover it with the other tub; you must then be careful to sprinkle it with warm water as often as may be necessary. Then carry the two tubs closely joined, taking care they cover each other, into a warm vault, or cellar, and at the end of fifteen days you may gather a fine salad.

To preserve Strawberry Plants from the Heat of the Sun, &c.

Sir Joseph Banks, from a variety of experiments, and the experience of many years, recommends a general revival of the now almost

obsolete practice of laying straw under strawberry plants, when the fruit begins to swell; by which means the roots are shaded from the sun, the waste of moisture by evaporation prevented, the leaning fruit kept from damage, by resting on the ground, particularly in wet weather, and much labour in watering saved. Twenty trusses of long straw are sufficient for 1800 feet of plants.

Directions for managing Strawberries in Summer.

On the management of strawberries in June and July, the future prosperity of them greatly depends; and if each plant has not been kept separate, by cutting off the runners, they will be in a state of confusion, and you will find three different sorts of plants.

1. Old plants, whose roots are turned black, hard, and woody.
2. Young plants, not strong enough to flower.
3. Flowering plants, which ought only to be there, and perhaps not many of them.

Before the time of flowering is quite over, examine them, and pull up every old plant which has not flowered; for, if once they have omitted to flower, you may depend upon it they will never produce any after, being too old, and past bearing; but to be fully convinced, leave two or three, set a stick to them, and observe them next year.

If the young plants, runners of last year, be too thick, take some of them away, and do not leave them nearer than a foot of the scarlet, alpines, and wood, and fifteen or sixteen inches of all the larger sorts; and in the first rainy weather in July or August, take them all up, and make a fresh plantation with them, and they will be very strong plants for flowering next year.

Old beds, even if the plants be kept single at their proper distance, examine, and pull all the old plants which have not flowered.

When the fruit is nearly all gathered, examine them again, and cut off the runners; but if you want to make a fresh plantation, leave some of the two first, and cut off all the rest. Then stir up the ground with a trowel, or three-pronged fork, and in August they will be fit to transplant.

If you have omitted in July do not fail in August, that the runners may make good roots to be transplanted in September, for, if later, the worms will draw them out of the ground, and the frost afterwards will prevent them from striking root; the consequence of which is, their not flowering the next spring; and you will lose a year.

To cultivate the common Garden Rhubarb.

It is not enough to give it depth of good soil, but it must be watered in drought; and in winter must be well covered with straw or dung. If this is attended to, your rhubarb will be solid when taken out of the ground; and your kitchen, if a warm one, when cut into large pieces, will soon fit it for use.

Method of cultivating and curing Turkey Rhubarb from Seed.

The seed should be sown about the beginning of February, on a bed of good soil (if rather sandy, the better), exposed to an east or west aspect in preference to the south; a full sun being prejudicial to the vegetation of the seeds, and to the plants whilst young.

The seeds are best sown moderately thick, (broad cast) treading them

regularly in, as is usual with parsnips and other light seeds, and then raking the ground smooth. When the season is wet, make a bed for sowing the rhubard seeds upon, about two feet thick, with new dung from the stable, covering it near one foot thick with good soil. The intent of this bed is not for the sake of warmth, but solely to prevent the rising of earth worms, which in a moist season will frequently destroy the young crop.

If the seed is good, the plants often rise too thick; if so, when they have attained six leaves, they should be taken up carefully (where too close), leaving the standing crop eight or ten inches apart: those taken up may be planted at the same distance in a fresh spot of ground, in order to furnish other plantations. When the plants in general are grown to the size that cabbage plants are usually set out for a standing crop, they are best planted where they are to remain, in beds four feet wide, one row along the middle of the bed, leaving two yards distance betwixt the plants, allowing an alley between the beds about a foot wide, for conveniency of weeding the plants.

In the autumn, when the decayed leaves are removed, if the shoveling of the alleys are thrown over the crowns of the plants, it will be found of service.

Cultivation of Turkey Rhubarb by Offsets.

Slip off several offsets from the heads of large plants: set them with a dibble about a foot apart, in order to remove them into other beds, and in the autumn they will be in a thriving state.

Method of curing Rhubarb.

The plants may be taken up, either early in the spring or in autumn, when the leaves are decayed, in dry weather if possible; when the roots are to be cleared from dirt (without washing), let them be cut into pieces, and with a sharp knife freed from the outer coat, and exposed to the sun and air for a few days, to render the outside a little dry.

In order to accelerate the curing the largest pieces, a hole may be scooped out with a penkinfe; these and the smaller parts are then to be strung on packthread, and hung up in a warm room, where it is to remain till perfectly dry. Each piece may be rendered more sightly by a common file, fixing it in a small vice during that operation; afterwards rub over it a very fine powder, which the small roots furnish in beautiful perfection, for this and every other purpose where rhubarb is required.

An easier and simpler method of drying rhubarb is, after cutting the root into handsome pieces, to wrap up each separately, in one or more pieces of whitish-brown paper, and then to place them on the hob of a common Bath stove. Lemon and orange peel dry beautifully in this way.

Proper Soil for the Culture of Turnips.

Sandy loams, in good heart, are most favourable to their growth, though they will thrive well on strong loams, if they are not wet; but on clayey, thin, or wet soils, they are not worth cultivating; for though a good crop may be raised on such ground, when well prepared and dunged, more damage is done by taking off the turnips in winter, in poaching the soil, than the value of the crop will repay.

Preservation of Succulent Plants.

Green succulent plants are better preserved after a momentary immersion in boiling water, than otherwise. This practice has been successfully used in the preservation of cabbage, and other plants, dried for keeping; it destroys the vegetable life at once, and in a great degree prevents that decay which otherwise attends them,

Various useful Properties of Tobacco to Gardeners.

Tobacco is employed for so many different uses, that there is no person possessed of a garden, but will find both pleasure and profit in the cultivation of it, especially as it is now at such a high price. The seed is very cheap, and may be procured of most nurserymen, and will answer the same end as the foreign for most purposes, and considerably cheaper.

(The cultivation of tobacco, however, for economical purposes, is prohibited in Great Britain and Ireland.)

Uses to which it may be applied.—1. To florists, for two elegant annual plants to decorate the borders of the flower garden; or, on account of their height, to fill up vacant places in the shrubberies; or, when put into pots, they will be very ornamental in the green-house during the winter.

2. Kitchen gardeners would in a few days lose their crops of melons, if not immediately fumigated with tobacco smoke, when attacked by the red spider; and it is useful to destroy the black flies on cucumbers in frames.

3. Fruit-gardeners. When peach and nectarine trees have their leaves curled up, and the shoots covered with smother flies, or the cherry trees have the ends of the shoots infested with the black dolphin fly, canvas, pack-sheets, or doubled mats, nailed before them, and frequently fumigated under them, will destroy those insects.

4. Forcing-gardeners, who raise roses and kidney-beans in stoves, can soon destroy the green flies which cover the stalks and buds of roses, and the insects which appear like a mildew on kidney-beans, by the assistance of the fumigating bellows.

5. Nurserymen. When the young shoots of standard cherry trees, or any other trees, are covered with the black dolphin flies, an infusion is made with the leaves and stalks of tobacco; a quantity is put into an earthen pan, or small oblong wooden trough: one person holds this up, whilst another gently bends the top of each tree, and lets the branches remain about a minute in the liquor, which destroys them.

6. Graziers, when their sheep are infected with the scab, find relief from making a sheep-water with an infusion of the leaves and stalks. Moles, when only a few hills are at first observed, may probably be soon driven out of the ground, by fumigating their holes.

7. Herb tobacco is also greatly improved by having some of the leaves, when dried, cut with a pair of scissars, and mixed with the herbs in any quantity you may think proper, according to the strength you require, and save you the expence of buying tobacco.

The herbs generally used for this purpose are coltsfoot and wood betony leaves: the leaves and flowers of lavender, rosemary, thyme, and some others of the like nature.

REFINING METALS.

Cupellation. Gold and silver being the only metals capable of withstanding the action of very strong heat, are therefore called perfect metals. All other metals are reduced to the state of oxydes when exposed to a violent fire with access of air. Gold and silver may therefore be purified from all the baser metals, by keeping them fused till the alloy be destroyed: but this process would be very expensive, from the great consumption of fuel, and would be exceedingly tedious. A shorter and more advantageous method of performing this operation has been discovered.

A certain quantity of lead is added to the alloy of gold and silver, and the whole is exposed to the action of the fire.

Lead is one of the metals which is most quickly converted by heat into an oxyde, which is easily melted into a semi-vitrified, and powerful vitrifying matter, called litharge. By increasing the proportion of imperfect metals, it prevents them from being so well covered and protected by the perfect metals; and by uniting with these imperfect metals, it communicates to them its property of being very easily oxydated. By its vitrifying and fusing property, which it exercises with all its force upon the calcined and naturally refractory parts of the other metals, it facilitates and accelerates the fusion, scorification, and separation of these metals. The lead, which in this operation is scorified, and scorifies along with it the imperfect metals, separates from the metallic mass, with which it is then incapable of remaining united. It floats upon the surface of the melted mass, and becomes semi-vitrified. But the litharge so produced would soon cover the melted metal, and by preventing the access of air, would prevent the oxydation of the remaining imperfect metals. To remedy this, such vessels are employed as are capable of imbibing and absorbing in their pores the melted litharge, and thus remove it out of the way. Or, for large quantities, vessels are so constructed, that the fused litharge, besides being soaked in, may also drain off through a channel made in the corner of the vessel.

Experience has shewn, that, for this purpose, vessels made of lixiviated wood or bone ashes are most proper. These vessels are called cupels, and this process is called cupellation. The cupels are flat and shallow. The furnace ought to be vaulted, that the heat may be reverberated upon the surface of the metal during the whole time of the operation. Upon this surface a crust or dark coloured pellicle is continually forming. In the instant when all the imperfect metal is destroyed, and consequently the scorification ceases, the surface of the perfect metal is seen, and appears clean and brilliant. This forms a kind of fulguration, or corruscation, called lightning. By this mark, the metal is known to be refined.

Purification of gold by antimony.—When gold contains only a small quantity of alloy, it may be separated from them by melting it in a crucible that will hold twice its quantity at least, and throwing upon it, whilst in fusion, twice its weight of crude antimony (sulphuret of antimony). The crucible is then to be covered, and the whole is to be kept in a melting state for some minutes; and when the surface sparkles, it is quickly to be poured into an inverted cone, which has been previously heated and greased. By striking the cone on the ground, the me-

tal will come out when cold. The compact mass consists of two substances; the upper part is the sulphur of the crude antimony, united with the impure alloy; and the lower part is the gold, united to some of the regulus of antimony, proportionable to the quantities of metals which have been separated from the gold, which are now united with the sulphur of the antimony. This regulus of gold may be separated from the regulus of antimony by simple exposure to less heat than will melt the gold, because antimony is volatile in such a heat, and is then dissipated. If the gold is not sufficiently purified by this first process (which is often the case), it must be repeated a second, and even a third time. When a part is dissipated, more heat is required to keep the gold in fusion; therefore the fire must be increased towards the end of the operation. The purification is completed by means of a little nitre thrown into the crucible, which effectually calcines the remaining regulus of antimony. Sometimes, after these operations, the gold is found to be deprived of much of its usual ductility; this, however, is easily restored to it, by fusing it with nitre and borax. The first part of this process is founded on a property of sulphur, by which it is incapable of uniting with gold, and is strongly disposed to unite with all other metallic substances, excepting platina and zinc; and also upon the property of sulphur, that it has less affinity with regulus of antimony than with any metallic substance with which it can unite. Hence, when gold, alloyed with silver, copper, iron, lead, &c. is fused together with sulphuret of antimony, these latter metals unite with the sulphur of the antimony, while the reguline part, disengaged from them by its sulphur, unites with the gold.

The sulphur of the antimony, though it unites with the baser metals, does not destroy them, but forms with them a scoria, from which they may be separated by treatment as an ore.

Parting.

When the quantity of silver united to the gold is considerable, they may be separated by other processes. Nitric acid, muriatic acid, and sulphur, which cannot dissolve gold, attack silver very easily; and therefore these three agents furnish methods of separating silver from gold, which operation is called parting.

Parting by nitric acid is the most convenient, and therefore most used, and is even almost the only one employed by goldsmiths and coiners. Wherefore it is called simply parting. That made with muriatic acid is only made by cementation, and is known by the name of concentrated parting. Lastly, parting by sulphur is made by fusion, and is therefore called dry parting.

Parting gold from silver by nitric acid or aquafortis.—Although parting by nitric acid be easy, it cannot succeed, or be very exact, unless we attend to some essential circumstances. The gold and silver must be in a proper proportion; for if the gold be in too great a quantity, the silver would be covered and guarded by it from the action of the acid; therefore, when assayers do not know the proportion of gold to silver in the mass, they rub the mass upon a touch-stone (which is usually composed of black basaltes, though black pottery will do very well), so as to leave a mark upon it; they then make similar marks with their proof-needles (which are needles composed of gold and silver alloyed together in graduated proportions), and by comparing the co-

lour of the several marks, they discover the probable scale of admixture. If the trial shews, that in any given mass the silver is not to the gold as three to one, this mass is improper for the operation of parting by aquafortis. In this case, the quantity of silver necessary to make any alloy of that proportion must be added. This operation is called quartation, because it reduces the gold to a fourth of the whole mass. No inconvenience arises from too great quantity of silver, except a waste of aquafortis. The nitric acid or aquafortis employed, must be very pure, and especially free from mixture of sulphuric and muriatic acids. Its purity must therefore be ascertained; and if this be found not sufficient, the acid must be purified by nitrate of silver.

If the purity of the nitric acid were not attended to, a quantity of silver proportionable to these two foreign acids would be separated during the solution; and this portion of silver converted by these acids to sulphate of silver, and to muriate of silver, would remain mingled with the gold.

When the metallic mass is properly alloyed, it is to be reduced to plates rolled up spirally, called cornets, or to grains. These are to be put into a matrass, and upon them a quantity of aquafortis is to be poured, the weight of which is to that of the silver as three to two; and as the nitric acid employed for this operation is rather weak, the solution is assisted, especially at first, by the heat of a sand-bath, in which the matrass is to be placed. When, notwithstanding the heat, no further mark of solution appears, the aquafortis charged with silver is to be decanted. Fresh nitric acid is to be poured into the matrass, stronger than the former, and in less quantity, which must be boiled in the remaining mass, and decanted as the former. Aquafortis must even be boiled a third time on the remaining gold, that all the silver be certainly dissolved. The gold is then to be washed with boiling water. This gold is very pure, if the operation has been performed with due attention. It is called gold of parting.

The silver dissolved in the aquafortis may be separated either by distillation—in which case all the aquafortis is recovered very pure, and fit for another parting—or it may be precipitated by some substance which has a greater affinity than this metal with nitric acid. Copper is generally employed for this purpose in the mint.

The solution of silver is put into copper vessels. The aquafortis dissolves the copper, and the silver precipitates. When the silver is all precipitated, the new solution is decanted, which is then a solution of copper. The precipitate is to be well washed, and may be melted into an ingot. It is called parted silver. When this silver has been obtained from a mass which had been refined by lead, and when it has been well washed from the solution of copper, it is very pure. Or the silver may be separated from the nitric acid by adding to it muriatic acid, with which it forms muriate of silver. Muriate of silver may be decomposed by mixing it with soda, and exposing it to a sufficient heat in a crucible, whereby the soda unites to the muriatic acid, and sets the silver free.

The refiners frequently employ this solution of copper obtained in the process of parting, for making verditer; which is prepared by adding quick lime to the solution; a precipitate takes place, which is the blue pigment known by the name of verditer.

Parting gold from silver by cementation.—This is also called parting

by concentration, and is usually employed when the quantity of gold is so great to that of the silver, as to render it a difficult task by aquafortis. The mixed metal to be cemented is to be reduced to plates, as thin as small pieces of money. At the bottom of the crucible, or melting-pot, is to be laid a stratum of cement, composed of four parts of bricks powdered and sifted, one part of green copperas (sulphate of iron) calcined to redness, and one part of common salt, about the thickness of a finger in depth. Upon this stratum a layer of plates of the metal is to be placed, and then another stratum of cement, and so on till the crucible is filled. It is now to be placed in a furnace, or oven (after a top has been luted on the crucible), and exposed for twenty-four hours, till it is gradually made red hot, but by no means to be melted. The fire is now left to go out, and the metal is permitted to cool, that it may be separated from the cement, and boiled repeatedly in large quantities of pure water. This gold is afterwards to be tried on a touch-stone; and if it is not sufficiently purified, the process must be performed a second time. By the above method, we see how powerfully silver is dissolved by marine acid, when it is in a state of subtile vapour, which is disengaged from the common salt of the cement. Instead of common salt, nitre may be used, as the nitrous acid readily dissolves silver; but the mixture of common salt and nitre together is highly injudicious, because the joint acids are able to dissolve some of the gold with the silver. Whatever silver has been separated will now remain in the cement; but it may be freed from this by lead, in the method described in cupellation.

Parting gold from silver in the dry way.—This is also called parting by fusion, and is performed by means of sulphur, which has the property of uniting easily with silver, while it does not attack gold. This dry parting is troublesome, and even expensive, and ought not to be undertaken but when the silver far exceeds the gold, because sulphur will not separate it so easily as aquafortis, and will therefore require a further application to cupellation and solution.

Refining Silver by Nitre.

The principle upon which this operation is founded consists in the property of nitre to oxydate very powerfully all base metals; whereas, on the contrary, the noble metals are not at all affected by it. For as the metallic oxydes and glasses do not remain united with reguline metals, and as these latter sink to the bottom when in fusion, on account of their greater specific gravity, they may be easily parted from the scoriæ.

The silver to be purified by nitre is to be first granulated, and then mixed with a fourth part of its weight of dry nitre, an eighth part of potass, and a little common glass, all in powder. This mixture is to be put into a good crucible, two-thirds of which only must be full. This crucible is to be covered with a smaller crucible inverted, in the bottom of which a small hole has been made, and luted to the former. The crucibles, thus disposed, are to be placed in a furnace capable of drawing air sufficiently to make the fire intense enough only to melt the silver. Then charcoal is to be put into the furnace to such a height, that only the top of the inverted crucible shall be uncovered. The coal is then to be kindled, and the vessels to be made moderately red; a hot coal ought to be put upon the small hole in the bottom of the inverted

crucible. If a shining light be observed round this coal, and a slight hissing noise at the same time heard, we may know that the operation proceeds well. The fire must be sustained at the same degree till these appearances cease, when it must be increased, so that the silver be well melted, and then the crucibles are to be taken out of the furnace. The larger crucible is to be broken when it is cold, and the silver will be found at the bottom covered with green alkaline scoriæ. If the metal be not sufficiently ductile, the operation must be again repeated.

Some silver is apt to be lost in this operation, by the swelling and detonation of the nitre, which often forces it through the hole in the upper crucible, unless great care be used; nevertheless, this method has its advantages, being much more expeditious than cupellation.

Separating Silver from Copper by Eliquation.

When it is desired to separate, in the large way, a small quantity of silver from much copper with which it is alloyed, the process called eliquation is resorted to. This operation is grounded on the nearer affinity of silver with lead than with copper; in consequence of which it fuses, and combines with lead at a degree of heat in which copper continues unfused.

Whitening Silver by Boiling.

Whitening of silver by boiling is one of the methods of parting copper from silver in the humid way. For this purpose, silver wrought in any shape is first ignited to redness, and afterwards boiled in a ley of muriate of soda, and acidulous tartrite of potass. By so doing, the copper is removed from the surface, and the silver receives a better appearance.

Precipitating Silver by Copper.

Copper has a much greater affinity with oxygen than silver; consequently, the silver is precipitated from its solutions as a fine silver dust, by metallic copper. This likewise affords a means to discover what portion of silver may be contained in an alloy of silver and copper. A quantity of the mixture determined by weight is dissolved in nitric acid; the solution is diluted with water, filtered, and a plate of copper hung in it, till no more precipitate falls down. Then the weight of the precipitate, when edulcorated, is compared with that of the whole alloyed metal put to trial.

This silver dust well washed, and mixed with gum water, serves as a pigment in water painting.

Separating Silver from Copper by an Alkaline Sulphuret.

The affinity of copper with sulphur is stronger than that of silver. Upon this ground, liver of sulphur (sulphuret of potass) has been proposed as an expedient to free silver from copper; for if silver holding copper be fused with alkaline sulphuret, the base metal combines with the latter, and is converted into scoriæ floating on the silver.

Mr. Keir's Mode of separating Silver from Copper.

Chemists have long been acquainted with the compound acid, called aqua regia (nitro muriatic acid), which has the exclusive property of dissolving gold. The discovery of a compound acid, acting exclusively upon silver, is owing to our contemporary, Mr. Keir.

This compound acid is made by dissolving one pound of nitrate of potass (common nitre or saltpetre), in eight or ten pounds of sulphuric acid (oil of vitriol), or by mixing together sulphuric and nitric acids. This acid dissolves silver easily, while it will not attack copper, iron, lead, gold, or platina.

These properties have rendered it capable of a very useful application in the arts. Among the manufactures at Birmingham, that of making vessels of silver, plated on copper, is a very considerable one. On cutting out the rolled plated metal into pieces of the required form and sizes, there are many shreds, or scraps, as they are called, unfit for any purpose, but the recovery of the metals, by separating them from each other. The easiest and most economical method of parting these two metals, so as not to lose either of them, is an object of some consequence to the manufacturers. For this purpose, two modes were practised, one, by melting the whole of the mixed metals with lead, and separating them by eliquation and testing; and the second, by dissolving both metals in sulphuric acid, with the help of heat, and by separating the sulphate of copper, by dissolving it in water, from the sulphat of silver, which is afterwards to be reduced and purified.

In the first of these methods, there is a considerable waste of lead and copper; and in the second, the quantity of sulphuric acid employed is very great: as much more is dissipated in the form of sulphureous acid than remains in the composition of the two sulphates.

Some years ago, Mr. Keir communicated to an artist the method of effecting the separating of silver and copper, by means of the above-mentioned compound of sulphuric acid and nitre. It is now commonly practised by the manufacturers at Birmingham, and is much more economical, and much easier executed, than any of the above-mentioned methods; for nothing more is necessary than to put the pieces of plated metal into a glazed earthen pan, to pour upon them some of the acid liquor, to stir them about, that the surfaces may be frequently exposed to fresh liquor, and to assist the action by a gentle heat, from 100° to 200° of Fahrenheit's thermometer.

When the liquor is nearly saturated, the silver is to be precipitated from it by common salt, which forms muriate of silver, or luna cornea, easily reducible to a metallic state, by melting in a crucible, with a sufficient quantity of potass; and lastly, by refining the melted silver, if necessary, with a little nitre thrown upon it. In this manner, the silver will be obtained sufficiently pure, and the copper will remain unchanged. Otherwise, the silver may be precipitated in its metallic state, by adding to the solution of silver a few of the pieces of copper, and a sufficient quantity of water to enable the liquor to act upon the copper.

Method of obtaining Gold in a pure State.

Perfectly pure gold may be obtained, by dissolving the gold of commerce in nitro muriatic acid, and precipitating the metal, by adding a weak solution of sulphate of iron. The precipitate, after being well washed and dried, is pure gold.

Method of obtaining Silver in a pure State.

Dissolve the silver of commerce in nitric acid, and add to it some muriatic acid; a white curdy precipitate will be formed, which is muriate of silver. To reduce muriate of silver to the metallic state, let one

part of it be mixed with three of soda, and exposed to a white heat. When the mixture is well fused, suffer it to cool; then break the crucible, and separate the pure silver from the muriate of soda which has been formed.

Method of obtaining pure Copper.

Let the copper of commerce be dissolved in muriatic acid, and precipitate it by a polished plate of iron; the precipitate is pure copper.

Of making Brass, and other Alloys of Copper.

Brass is made by fusing together lapis calaminaris (which is an ore of zinc) and copper.

Tombac is formed by melting together twelve parts of copper with three of zinc.

Gun-metal consists of nine parts of copper and one of tin.

Bell-metal is copper alloyed with one-sixth of tin. A smaller proportion of tin is used in making church bells than clock bells, and a little zinc is added for the bells of repeating-watches, and other small bells.

Cock-metal is made with copper alloyed with zinc and lead.

The gold coins of this country are composed of eleven parts of gold and one of copper.

Standard silver contains fifteen parts of silver and one of copper.

POTTERY.

Pottery, or the art of making vessels of baked earth, is of the remotest antiquity. The ancient Greeks and Etruscans particularly excelled in it. Porcelain, the most perfect species of pottery, has been made in China from time immemorial.

Alumine and silex are two substances of which every kind of earthenware is made. Clay alone shrinks and cracks; the flint gives it solidity and strength.

Common pottery, such as coarse brown jugs, &c. are made of the ordinary clays, which are a mixture of sand and clay, coloured by oxyde of iron. The clay is well ground, or kneaded, and a lump of it is put upon the centre of a wheel which is kept in motion; then, by means of the workman's hand, or by proper tools, it is formed into the required shape. The pieces are then dried moderately, so as to bear being removed without danger; they are then covered with a glaze, made from semi-vitreous oxyde of lead, and put into a furnace, where they are baked. Some sorts are glazed by throwing sea-salt into the furnace among the different pieces of pottery. The salt is decomposed, and the vapours of it form a glazing upon the vessels; but this, though a very simple and ingenious method, does not form a good glazing.

English stone-ware is made of tobacco-pipe clay, mixed with flints calcined and ground. This mixture burns white, and vessels of this were at first glazed with sea-salt. Mr. Wedgwood was the first who introduced a superior kind of it, now so common, called queen's-ware. The tobacco-pipe clay is much beat in water; by this process the finer parts remain suspended in the water, while the coarser, sand, and other impurities, fall to the bottom. The thick liquid, consisting of water and the finer parts of the clay, is further purified by passing it through hair and lawn sieves, of different degrees of fineness. After this, the

liquid is mixed (in various proportions for various wares) with another liquor of the same density, and consisting of flints calcined, ground, and suspended in water. The mixture is then dried in a kiln; and being afterwards beaten to a proper temper, it becomes fit for being formed at the wheel into dishes, plates, bowls, &c. When this ware is to be put into the furnace to be baked, the several pieces of it are placed in cases made of clay, called seggars, which are piled one upon another in the dome of the furnace; a fire is then lighted, and the ware is brought to a proper temper for glazing. It is then dipped into a glaze, made by mixing together in water, till it becomes as thick as cream, 112 parts of white lead, 24 parts of ground flint, and 6 parts of ground flint-glass. The ware, by being baked, acquires a strong property of imbibing moisture, and in this state is called biscuit: when dipped into the glaze, therefore, it greedily attracts it into its pores, and the ware presently becomes dry. It is then exposed a second time to the fire, by which means the glaze it has imbibed is melted, and a thin glassy coat is formed upon its surface. The colour of the coat is more or less yellow, according as a greater or less proportion of lead has been used. The lead is principally instrumental in producing the glaze, as well as in giving it the yellow colour; for lead, of all the substances hitherto known, has the greatest power of promoting the vitrification of the substances with which it is mixed. The flint serves to give a consistency to the lead during the time of its vitrification, and to hinder it from becoming too fluid, and running down the sides of ware, and thereby leaving them unglazed.

This glazing, made by means of lead, is liable to be attacked by acids, and is supposed to be productive of deleterious effects, when employed in jars used for pickling, &c.

The following composition has been recommended as a substitute.

To make this, white glass and soda, in equal portions, must be very finely pulverized, carefully sifted, and well mixed. The mixture is then exposed to a strong heat, till it is rendered very dry. It is afterwards put into vessels which have been already baked; is then melted, and the varnish is made. It may be applied in the same manner as that in common use.

The advantage of it is, that it is safe, and can have none of those poisonous effects which arise from the decomposition of the lead varnish.

Porcelain, or *china*, is a semi-vitrified earthen ware, of an intermediate nature between common ware and glass. Chinese porcelain is composed of two ingredients, one of which is a hard stone, called petuntse, which is carefully ground to a very fine powder; and the other, called kaolin, is a white earthy substance which is intimately mixed with the ground stone. The former is of the siliceous, and the latter of the aluminous genus.

The Chinese long excelled in the art of making porcelain, but it is now made in various parts of Europe of an equally good quality, and much more ornamental.

By genuine or true porcelain, such pottery is understood as is infusible in the strongest fire excited in furnaces; is hard, but not so brittle as glass; proof against any sudden and great changes of heat and cold; finely grained, dense, and without gloss in the fracture; not glassy, and of a peculiar transparency.

Several compositions of mingled earths may yield a true porcelain,

by being burnt; and the porcelains of various countries differ in their mixtures. But the principal basis of any true porcelain is that kind of clay which becomes white by baking, and which, either by intermingled heterogeneous earth, or by particular additions, undergoes in the fire an incipient vitrification, in which the true nature of porcelain consists. Feldspar and gypsum, if added, may give that property to infusible clay.

When porcelain is to be made, the clay is properly selected, carefully washed from impurities, and again dried. It is then finely sifted, and most accurately mingled with quartz, ground very fine; to which, then, is added some burnt and finely pulverized gypsum. This mass is worked with water to a paste, and duly kneaded; it is usually suffered to lie in this state for years. The vessels and other goods formed of this mass are first moderately burnt in earthen pots, to receive a certain degree of compactness, and to be ready for glazing. The glazing consists of an easily melted mixture of some species of earths, as the petrosilex or chert, fragments of porcelain and gypsum, which, when fused together, produce a crystalline, or vitreous mass, that, after cooling, is very finely ground, and suspended in a sufficient quantity of water. Into this fluid the rough ware is dipped, by which the glazing matter is deposited uniformly on every part of its surface. After drying, each article is thoroughly baked or burned in the violent heat of the porcelain furnace. It is usual to decorate porcelain by paintings, for which purpose, enamels or pastes, coloured by metallic oxydes, are used, so easy of fusion as to run in a heat less intense than that in which the glazing of the ware melts.

Delft-ware, so called because first made at Delft in Holland, is a kind of pottery made of sand and clay, and but slightly baked, so that it resists sudden application of heat. Articles made of this are glazed with an enamel, composed of common salt, sand ground fine, oxyde of lead, and oxyde of tin. The use of the latter is to give opacity to the glaze.

Tobacco-pipes require a very fine, tenacious, and refractory clay, which is either naturally of a perfectly white colour, or, if it have somewhat of a grey cast, will necessarily burn white. A clay of this kind must contain no calcareous or ferruginous earth, and must also be carefully deprived of any sand it may contain, by washing. It ought to possess, besides, the capital property of shrinking but little in the fire. If it should not prove sufficiently ductile, it may be meliorated by the admixture of another sort. Last of all, it is beaten, kneaded, ground, washed, and sifted, till it acquires the requisite degree of fineness and ductility.

When, after this preparation, the clay has obtained a due degree of ductility, it is rolled out in small portions to the usual length of a pipe, perforated with a wire, and put together with the wire, into a brass mould rubbed over with oil, to give it its external form; after which it is fixed into a vice, and the hollow part of the head formed with a stopper. The pipes, thus brought into form, are cleared of the redundant clay that adheres to the seams, a rim or border is made round the head, they are then marked with an iron stamp upon the heel, and the surfaces smoothed and polished. When they are well dried, they are put into boxes, and baked in a furnace, In the Dutch manufactories, these boxes consist of conical pots made of clay, with conical

lids, with a tube passing through the middle of them, by which the pipes are supported; or else, they are long clay boxes, in which the pipes are laid horizontally, and stratified with fragments of pipes pounded small.

Lastly, the pipes, when baked, are covered with a glazing or varnish, and afterwards rubbed with a cloth. This glazing consists of a quarter of a pound of soap, two ounces of white wax, and one ounce of gum arabic, or tragacanth, which are all boiled together in five pints of water, for the space of a few minutes.

MANUFACTURE OF GLASS.

This beautiful material is not of modern invention; it was known to the ancient Romans, but it was by no means common among them, and they do not appear to have had the method of forming it into vessels of various shapes as is practised at present.

Glass is made by fusing together silex and potass, or soda, in proper proportions. Sea sand, which consists almost entirely of quartz and flints reduced to powder, is generally used for this purpose. The alkali is generally procured from the burning of sea weeds; these are cut, dried, and burned in pits dug in the ground; after a sufficient quantity of them have burned in the same pit, a melted or liquid mass is found in the bottom, which, after being well stirred, is suffered to cool; it is then called kelp, and consists of a mixture of soda, potass, and parts of half burnt weeds, together with shells, sand, and other impurities.

When the ingredients of which glass is composed are perfectly fused, and have acquired a certain degree of heat, which is known by the fluidity of the mass, part of the melted matter is taken out at the end of a long hollow tube, which is dipped into it, and turned about, till a sufficient quantity is taken up; the workman then rolls it gently upon a piece of iron, to unite it more intimately. He then blows through the tube, till the melted mass at the extremity swells into a bubble, after which he rolls it again on a smooth surface to polish it, and repeats the blowing, until the glass is brought as near the size and form of the vessel required as he thinks necessary.

If it be a common bottle, the melted glass at the end of the tube is put into a mould of the exact size and shape of its body, and the neck is formed on the outside, by drawing out the ductile glass.

If it be a vessel with a wide orifice, the glass in its melted state is opened and widened with an iron tool; after which being again heated, it is whirled about with a circular motion, and by means of the centrifugal force thus produced, is extended to the size required. Should a handle, foot, or any thing else of the kind, be required, these are made separately, and stuck on in its melted state.

Window-glass is made in a similar manner, except that the liquid mass at the end of the tube is formed into a cylindrical shape, which being cut longitudinally by scissars or sheers, is gradually bent back until it becomes a flat plate.

Large plate glass, for looking-glasses, &c. is made by suffering the mass in a state of complete fusion to flow upon a table, with iron ledges to confine the melted matter, and as it cools, a metallic roller is passed over it, to reduce it to a uniform thickness. There are various kinds

of glass manufactured for different purposes; the principal of these are flint-glass, crown-glass, and bottle-glass.

Flint-glass is the densest, most transparent, colourless, and beautiful. It is sometimes called crystal. The best kind is said to be manufactured in London, from 120 parts of white siliceous sand, 40 parts of pearl ash, 35 of red oxyde of lead, 13 of nitrate of potass, and 25 of black oxyde of manganese. It is the most fusible glass. It is used for bottles, and other utensils, intended to be cut and polished, and for various ornamental purposes.

Crown-glass differs from the last, in containing no lead. It is made of soda and fine sand. It is used for panes of windows, &c.

Bottle-glass is the coarsest sort of all. It is made from kelp and common sand. Its green colour is owing to iron. It is the least fusible.

Glass is sometimes coloured by mixing with it while in a fluid state, various metallic oxydes. It is coloured blue, by the oxyde of cobalt; red, by the oxyde of gold; green, by the oxyde of copper or iron; yellow, by the oxyde of silver or antimony, and violet by the oxyde of manganese.

The hardness of glass is very considerable; its specific gravity varies from 2, 3, to 4, according to the quantity of metallic oxyde which enters into its composition. Though glass, when cold, is brittle, it is one of the most ductile bodies known. When liquid, if a thread of melted glass be drawn out, and fastened to a reel, the whole of the glass can be spun off; and by cutting the threads of a certain length, there is obtained a sort of feather of glass. A thread of glass may be thus drawn or spun so fine, as to be scarcely visible to the naked eye. Glass is almost perfectly elastic, and is one of the most sonorous bodies. Fluoric acid dissolves it at common temperatures, and alkalies in a great degree of heat. These are the only substances known which act upon it.

Glass utensils require to be gradually cooled in an oven: this operation is called annealing, and is necessary to prevent their breaking by change of temperature, wiping, or slight accidental scratches.

Two toys are made of unannealed glass, which, though commonly used for the amusement of children, exhibit phenomena which justly interest the curiosity of the philosopher; we mean Prince Rupert's drops, and the Bologna flask or philosophical phial.

Prince Rupert's drops are made, by letting drops of melted glass fall into cold water: the drop assumes by that means an oval form, with a tail or neck resembling a retort. These drops are said to have been first invented by Prince Rupert, and are therefore called by his name. They possess this singular property, that if a small portion of the tail is broken off, the whole bursts into powder, with an explosion; and a considerable shock is communicated to the hand that grasps it.

The *Bologna* or *philosophical phial*, is a small vessel of glass, which has been suddenly cooled, open at the upper end, and rounded at the bottom. It is made so thick at the bottom, that it will bear a smart blow against a hard body, without breaking; but if a little pebble, or piece of flint, is let fall into it, it immediately cracks, and the bottom falls into pieces: but unless the pebble or flint is large and angular enough to scratch the surface of the glass, it will not break.

The most generally received explanation of these facts is founded on

the assumption, that the dimensions of those bodies which are suddenly cooled, are larger than those which are more gradually cooled. The dimensions, therefore, of the smooth external surface of these glasses which are suddenly cooled, are supposed to be larger than is adapted to the accurate envelopement of the internal part, which is necessarily cooled in a more gradual manner; if, therefore, by a crack or scratch, a disjunction of the cohesion takes place, in the internal surface, the hidden action of the parts which remained in a state of tension, to recover that of perfect cohesion, is supposed to effect the destruction of the mass.

PROTECTION OF GROWINS CROPS FROM THE DEVASTATION OF VERMIN.

The good Effects of Elder in preserving Plants from Insects and Flies.

1. For preventing cabbage and cauliflower plants from being devoured and damaged by caterpillars.
2. For preventing blights, and their effects on fruit trees.
3. For preserving corn from yellow flies and other insects.
4. For securing turnips from the ravages of flies.

The dwarf elder appears to exhale a much more fœtid smell than the common elder, and therefore should be preferred.

The Use of Sulphur in destroying Insects on Plants, and its Benefit for Vegetation.

Tie up some flowers of sulphur in a piece of muslin or fine linen, and with this the leaves of young shoots of plants should be dusted, or it may be thrown on them by means of a common swan's-down puff, or even by a dredging-box.

Fresh assurances have been repeatedly been received of the powerful influence of sulphur against the whole tribe of insects and worms which infest and prey on vegetables. Sulphur has also been found to promote the health of plants, on which it was sprinkled; and that peach trees, in particular, were remarkably improved by it, and seemed to absorb it. It has likewise been observed, that the verdure, and other healthful appearances, were perceptibly increased; for the quantity of new shoots and leaves formed subsequently to the operation, and having no sulphur on their surfaces, served as a kind of comparative index, and pointed out distinctly the accumulation of health.

Methods of stopping the Ravages of the Caterpillars from Shrubs, Plants, and Vegetables.

Take a chafing-dish, with lighted charcoal, and place it under the branches of the tree, or bush, whereon are the caterpillars; then throw a little brimstone on the coals. The vapour of the sulphur, which is mortal to these insects, and the suffocating fixed air arising from the charcoal, will not only destroy all that are on the tree, but will effectually prevent the shrubs from being, that season, infested with them. A pound of sulphur will clear as many trees as grow on several acres.

Another method of driving these insects off fruit trees is, to boil together a quantity of rue, wormwood, and common tobacco (of each equal parts), in common water. The liquor should be very strong. Sprinkle this on the leaves and young branches every morning and evening during the time the fruit is ripening.

In the Economical Journal of France the following method of guarding cabbages from the depredations of caterpillars is stated to be infallible, and may, perhaps, be equally serviceable against those which infest other vegetables. Sow with hemp all the borders of the ground wherein the cabbage is planted: and, although the neighbourhood be infested with caterpillars, the space inclosed by the hemp will be perfectly free, and not one of these vermin will approach it.

To prevent the Increase of Pismires in Grass Lands newly laid down.

Make a strong decoction of walnut-tree leaves, and after opening several of the pismire's sandy habitations, pour upon them a quantity of the liquor, just sufficient to fill the hollow of each heap: after the middle of it has been scooped, throw in the contents from the sides, and press down the whole mass with the foot, till it becomes level with the rest of the field. This, if not found effectual at first, must be repeated a second or a third time, when they infallibly will be destroyed.

Liquor for destroying Caterpillars, Ants, and other Insects.

Take a pound and three quarters of soap, the same quantity of flower of sulphur, two pounds of champignons, or puff balls, and fifteen gallons of water. When the whole has been well mixed, by the aid of a gentle heat, sprinkle the insects with the liquor, and it will instantly kill them.

To destroy Ants.

Ants are destroyed by opening the nest, and putting in quick lime, and throwing water on it.

To prevent the Fly in Turnips.

Sow good and fresh seed in well manured and well prepared ground.

To prevent the Destruction of Field Turnips by Slugs.

A few years since, a considerable farmer, near Bath, observing the turnips in one of his fields strongly attacked by something, discovered, by accident, that the enemy was really a slug, and immediately prevented farther damage by well rolling the whole field, by night, which killed all the slugs.

This was the grand secret which was advertised for two thousand subscribers, at one guinea each, by W. Vagg, for destroying the fly in turnips, which it will not do!

For preventing Flies from destroying the Seedling Leaves of Turnips, &c.

Mix six ounces of flower of brimstone with three pounds of turnip seed, daily, for three days successively, in an earthen-glazed pot, and keep it close covered, stirring all together well at each addition, that the seed may be the more tainted with the sulphur; this will sow an acre of ground, and let the weather come wet or dry, it will keep the fly off till the third or fourth seedling leaf is formed; and by this time they will all be somewhat bitterish, and consequently very much out of danger of this little black flying insect, which, in summer time, may be seen in swarms on the wing near the ground, searching for, and settling on fresh bites, till they ruin thousands of acres.

To prevent Mice from destroying early sown Peas.

The tops of furze, or whins, chopped and thrown into the drills, and thus covered up (by goading them in their attempt to scratch) is an effectual preventive. Sea sand, strewed pretty thick upon the surface, has the same effect. It gets into their ears and is troublesome.

Another.—In the gardens in Devonshire, a simple trap is used to destroy mice. A common brick, or flat stone is set on one end, inclined at an angle of about forty-five degrees. Two strings, tied to a cracked stick, stuck in the ground, with loops at the ends of the strings, are brought round to the middle of the under part of the brick, and one loop being put into the other, a pea or bean, or any other bait, makes the string fast, so as to support the brick. When the animal removes the bait, the loops separate, and the brick, by falling, smothers the animal.

Usefulness of Mowing Weeds.

In the month of June, weeds are in their most succulent state, and in this state, especially after they have lain a few hours to wither, hungry cattle will eat greedily almost every species. There is scarcely a hedge border, or a nook, but what at that season is valuable; and it certainly must be good management to embrace the transient opportunity; for, in a few weeks, they will become nuisances.

Beneficial Purpose to which the Juice of Aloes may be applied.

In the East Indies aloes are employed as a varnish to preserve wood from worms and other insects; and skins, and even living animals are anointed with it for the same reason. The havock committed by the white ants in India first suggested the trial of aloe juice, to protect wood from them; for which purpose the juice is either used as extracted, or in solution by some solvent.

Efficacy of the Juice of Aloes on Ships' Bottoms.

Aloes have been found effectual in preserving ships from the ravages of the worm, and the adhesion of barnacles. The ship's bottom, for this purpose, is smeared with a composition of hepatic aloes, turpentine, tallow, and white lead. In proof of the efficacy of this method, two planks of equal thickness, and cut from the same tree, were placed under water, one in its natural state, and the other smeared with the composition. When, on taking them up, after being immersed eight months, the latter was found to be perfect as at first, while the former was entirely penetrated with insects, and in a state of absolute rottenness.

To bronze Plaster Figures.

Lay the figure over with isinglass size till it holds out, or without any part of its surface becoming dry or spotted; then, with a brush, such as is termed by painters a sash tool, go over the whole, observing carefully to remove any of the size (while it is yet soft) that may lodge on the delicate or sharp places, and set it aside to dry: when it has become so, take a little very thin oil gold-size, and, with as much of it as just damps the brush, go over the figure, allowing no

more of this size to remain than what causes it to shine. Set it apart in a dry place, free from smoke; and after it has remained there forty-eight hours, the figure is prepared for bronzing.

The bronze, which is almost an impalpable powder (and may be had at the colour shops, of all metallic colours) should be dabbed on with a little cotton wool; after having touched over the whole figure, let it stand another day; then, with a soft dry brush, rub off all the loose powder, and the figure will resemble the metal it is intended to represent, and possess the quality of resisting the weather.

To blue Mourning Buckles, Swords, &c.

Take a piece of grindstone and whetsone, and rub hard on the work, to take off the black scurf from it; then heat it in the fire, and as it grows hot the colour changes by degrees, coming first to a light, then to a dark gold colour, and lastly to a blue. Indigo and salad oil, ground together, is also used, by rubbing the mixture on the work, with a woollen cloth, while it is heating, leaving it to cool of itself.

Composition to take off Casts of Medals.

Melt eight ounces of sulphur over a gentle fire, and with it mix a small quantity of fine vermillion; stir it well together, and it will dissolve like oil; then cast it into the mould, which is first to be rubbed over with oil. When cool, the figure may be taken, and touched over with aqua-fortis, and it will look like fine coral.

Method of Sweeping Chimnies without employing Children, and the Danger attending the old Method pointed out.

Procure a rope for the purpose, twice the length of the height of the chimney; to the middle of it tie a bush (broom, furze, or any other), of sufficient size to fill the chimney; put one end of the rope down the chimney (if there be any windings in it, tie a bullet or round stone to the end of the rope), and introduce the wood end of the bush after the rope has descended into the chamber; then let a person pull it down. The bush, by the elasticity of its twigs, brushes the sides of the chimney as it descends, and carries the soot with it. If necessary, the person at top, who has hold of the other end of the rope, draws the bush up again; but, in this case, the person below must turn the bush, to send the wood end foremost, before he calls to the person at top to pull it up.

Many people, who are silent to the calls of humanity, are yet attentive to the voice of interest; chimnies cleansed in this way never need a tenth part of the repairs required where they are swept by children, who, being obliged to work themselves up by pressing with their feet and knees on one side, and their back on the other, often force out the bricks which divide the chimnies. This is one of the causes why, in many houses in London, a fire in one apartment always fills the adjoining ones with smoke, and sometimes even the neighbouring house. Nay, some houses have even been burnt by this means; for a foul chimney, taking fire, has been frequently known to communicate, by these apertures, to empty apartments, or to apartments filled with timber, where, of course, it was not thought necessary to make any examination, after extinguishing the fire in the chimney where it began.

New Method of clearing Feathers from their Animal Oil.

Take, for every gallon of clear water, a pound of quick-lime; mix them well together; and, when undissolved lime is precipitated in fine powder, pour off the clear lime-water for use at the time it is wanted. Put the feathers to be cleaned in another tub, and add to them a sufficient quantity of the clear lime-water to cover the feathers about three inches, when well immersed and stirred therein. The feathers, when thoroughly moistened, will sink down, and should remain in the lime water three or four days; after which, the foul liquor should be separated from the feathers, by laying them on a sieve. The feathers should be afterwards well washed in clean water, and dried on nets, the meshes being about the same fineness as those of cabbage nets. The feathers must, from time to time, be shaken on the nets; and, as they dry, they will fall through the meshes, and are to be collected for use. The admission of air will be serviceable in the drying, and the whole process may be completed in about three weeks. The feathers, after being thus prepared, will want nothing more than beating for use, either for beds, bolsters, pillows, or cushions.

To preserve the natural Colour in Petals of dried Flowers.

Nothing more is necessary than to immerse the petals for some minutes in alcohol. The colours will fade at first; but in a short time they will resume their natural tint, and remain permanently fixed.

Art of Gilding Iron or Steel.

Dissolve, in aquaregia, with the assistance of a little heat, as much gold as will fully saturate it; then, adding cream of tartar, form it into a paste. Any bright piece of steel or iron, such as the blade of a knife or razor, &c. being first wetted with water, or saliva, and then rubbed with this paste, will be instantly gilded in a beautiful manner; after which, it is to be washed with cold water. If a thicker coat of gold be desired, gold leaf may be laid on, and burnished hard, when it will adhere to the first gilding; and, if the nature of the thing gilded will admit of heat, by warming it, but not so as to become red hot, and then burnishing it, any thickness of gilding may be easily added.

Composition for Gilding Brass or Silver.

Take two ounces of gum-lac, two ounces of karabe, or yellow amber, forty grains of dragon's blood in tears, half a drachm of saffron, and forty ounces of good spirits of wine: infuse and digest the whole in the usual manner, and afterwards strain it through a linen cloth: when the varnish is used, the piece of silver or brass must be heated before it is applied: by this means it will assume a gold colour, which is cleaned, when soiled, with a little warm water.

To make Shell Gold.

Take the paring of leaf gold, or even the leaves themselves, and reduce them into an impalpable powder, by grinding them on a marble with honey; put this into shells where it will stick and dry; when you want to use it, dilute it with gum-water.

N. B. Shell silver is made the same way.

To clean Gold, and restore its Lustre.

Dissolve a little sal-ammoniac in urine; boil your soiled gold therein and it will become clean and brilliant.

To Silver Glass Globes.

Take two ounces of quicksilver, one ounce of bismuth, of tin and lead half an ounce of each: first put the tin and lead in fusion, then put in the bismuth, and when you perceive all in fusion, let it stand till almost cold, and then pour in the quicksilver.

After this take the glass globe, which must be very clean, and the inside free from dust, make a paper funnel, which put in the hole of the globe, as near the glass as you can, so that the amalgam, when you pour it in, may not splash and spot the glass: pour it in softly, and move it about that the amalgam may touch everywhere; if you find it begin to be curdly, hold it over a gentle heat, and it will flow again; the cleaner and finer your globe is, the looking-glass will be the better.

To Cut Glass.

Take a red hot shank of a tobacco-pipe, lay it on the edge of your glass, which will then begin to crack, then draw the shank end a little gently before, and it will follow any way you draw your hand.

Substitute for Hemp and Flax.

As hemp and flax (lint) are now very high priced, if the public would turn their attention to the *urtica dioica* (common nettle), an excellent hemp might be obtained from it, by cutting it just before the seed is ripe, and steeping it in water, as they do hemp or flax, and manufacturing it the same way; the root of the plant is esteemed to be diuretic, and the roots, boiled with alum, will dye yarn a yellow colour. It is likewise used by making a strong decoction of the young plant, and salt put to it, and bottled up, which will coagulate milk, and make it very agreeable; by which means that plant, which is an obnoxious weed, might be turned to good account.

To Braze or Solder Pieces of Iron.

This is done by means of thin plates of brass, melted between the pieces that are to be joined. If the work be very fine, as when two leaves of a broken saw are to be brazed together, cover it with pulverized borax, melted with water; that it may incorporate with the brass powder which is added to it: the piece must be then exposed to the fire without touching the coals, and heated till the brass is seen to run.

BLACKING.

In three pints of small beer, put two ounces of ivory black, and one pennyworth of brown sugar. As soon as they boil, put a desert-spoonful of sweet oil, and then boil slowly till reduced to a quart. Stir it up with a stick every time it is used.

Another.—Two ounces of ivory black; one tea-spoonful of oil of vitriol, one table-spoonful of sweet oil; and two ounces of brown sugar; roll the same into a ball, and to dissolve it add half a pint of vinegar.

Another.—Take ivory black and brown sugarcandy, of each two

ounces; of sweet oil a table-spoonful; add gradually thereto a pint of vinegar, cold, and stir the whole till gradually incorporated.

Another.—To one pint of vinegar add half an ounce of vitriolic acid, half an ounce of copperas, two ounces of sugarcandy, and two ounces and a half of ivory black: mix the whole well together.

Another.—Sweet oil, half an ounce; ivory black and treacle, of each half a pound; gum arabic, half an ounce; vinegar, three pints; boil the vinegar, and pour it hot on the other ingredients.

Another.—Three ounces of ivory black, one ounce of sugarcandy, one ounce of oil of vitriol, one ounce of spirits of salts, one lemon, one table-spoonful of sweet oil, and one pint of vinegar.—First mix the ivory black and sweet oil together, then the lemon and sugarcandy, with a little vinegar to qualify the blacking; then add your spirits of salts and vitriol, and mix them all well together.

N. B.—The last ingredients prevent the vitriol and salts from injuring the leather, and add to the lustre of the blacking.

Another.—Ivory black, two ounces; brown sugar, one ounce and a half; sweet oil, half a table-spoonful. Mix them well, and then gradually add half a pint of small beer.—*Proved.*

Another.—A quarter of pound of ivory black, a quarter of a pound of moist sugar, a table-spoonful of flour, a piece of tallow about the size of a walnut, and a small piece of gum arabic.—Make a paste of the flour, and while hot put in the tallow, then the sugar, and afterwards mix the whole well together in a quart of water, and you will have a beautiful shining blacking.

Blacking Balls for Shoes.

Mutton suet, four ounces; bees'-wax, one ounce; sugarcandy and gum-arabic, one drachm each, in fine powder; melt these well together over a gentle fire, and add thereto about a spoonful of turpentine, and ivory and lamp black, sufficient to give it a good black; while hot enough to run, you may make it into a ball, by pouring the liquor into a tin mould; or let it stand till almost cold: you may mould it in what form you please by the hand.

A celebrated Blacking Cake for Boots and Shoes.

Take one part of gum tragacanth, four parts of river water, two parts of neats'-foot, or some other softening lubricating oil, two parts of superfine ivory black, one part of Prussian blue in fine powder, or indigo, four parts of brown sugarcandy; boil the mixture; and when the composition is of a proper consistence, let it be formed into cakes of such a size that each cake may make a pint of liquid blacking.

Genuine Preparation of the Famous Chemical Liquid for Boot Tops, &c.

Many of the liquids, sold under various denominations, for the purpose of cleaning and restoring the colour of boot tops, &c. are found very imperfectly to answer that purpose, and often to injure the leather. The following genuine receipt may be fully relied on, for actually producing this desirable effect, as well as for readily taking out grease, ink spots, and the stains occasioned by the juice of fruit, red port wine, &c. from all leather or parchment:—Mix in a phial, one drachm of oxymuriate of potass with two ounces of distilled water; and, when the

salt is dissolved, add two ounces of muriatic acid. Then, shaking well together, in another phial, three ounces of rectified spirit of wine with half an ounce of the essential oil of lemon, unite the contents of the two phials, and keep the chemical liquid thus prepared closely corked for use. This chemical liquid should be applied with a clean sponge, and dried in a gentle heat; after which, the boot tops may be polished with a proper brush, so as to appear like new leather.

To clean Boot Tops, or any tanned Leather.

Boil one quart of milk; let it stand till cold, then take one ounce of oil of vitriol, one ounce of spirits of salts; shake them well together, and add one ounce of red lavender. You may put half a pint of vinegar, with the white of an egg beat to a froth.

To prevent Shoes from taking in Water.

One pint of drying oil, two ounces of yellow wax, two ounces of turpentine, and half an ounce of burgundy pitch, melted carefully over a slow fire. If new boots or shoes are rubbed with this mixture, either in the sun shine, or at some distance from the fire, with a sponge or soft brush, and the operation is repeated as often as they become dry, till the leather is fully saturated, they will be impervious to wet, and will wear much longer, as well as acquiring a softness and pliability that will prevent the leather from ever shrivelling.

Note.—Shoes or boots prepared as above ought not to be worn till perfectly dry and elastic, otherwise their durability would rather be prevented than increased.

To prevent Snow Water or Rain from penetrating the Soles of Shoes or Boots in Winter.

This simple and effectual remedy is nothing more than a little bees'-wax and mutton suet, warmed in a pipkin, until in a liquid state; then rub some of it slightly over the edges of the sole where the stitches are, which will repel the wet, and not in the least prevent the blacking from having the usual effect.

To restore the Lustre of Gold or Silver Lace, when tarnished.

When gold or silver lace happens to be tarnished, the best liquor that can be used for restoring its lustre is spirits of wine; it should be warmed before it is applied to the tarnished spot. This application will preserve the colour of the silk or embroidery.

To clean Gilt Buckles or Toys.

Rub a little soap on a soft brush, dip the same in water, and gently brush the article you intend cleaning for a minute or two, then wash the same clean off, wipe it and place it near the fire till it is perfectly dry, then burn a piece of bread, pound it to a fine powder, and brush your articles with it as you do silver goods with whitening.

A black Varnish for Gentlemen's old Straw or Chip Hats.

Take best black sealing wax, half an ounce; rectified spirit of wine, two ounces; powder the sealing-wax, and put it, with the spirit of wine, into a four ounce phial; digest them in a sand heat, or near a fire, till

the wax is dissolved; lay it on warm with a fine soft hair brush, before a fire, or in the sun. It gives a good stiffness to old straw hats, and a beautiful gloss equal to new, and resists wet. If the hats are very brown they may be brushed over with writing ink, and dried before the varnish is applied. Spirit of turpentine may probably be used in the place of the spirit of wine.

To prevent Gentlemen's Hats from being spotted after a Shower of Rain.

If your hat is wet from rain, or any other cause, shake it out as much as possible; then with a clean linen cloth or hankerchief wipe the hat very carefully as well as you can, observing, that in so doing you keep the beaver flat and smooth, in the same direction as it was first placed, then with your hands fix it in the original shape, and hang it at a distance from the fire to dry. A few hours after, or the next morning, lay the hat on a table, and brush it round and round several times with a soft brush in the proper direction, and you will find your hat not in the least injured by the rain.

If the gloss is not quite so high as you wish, take a flat iron, moderately heated, aud pass the same two or three times gently over the hat; brush it afterwards; and it will be nearly as handsome as when first sent home from the shop.

Preventives against the Ravages of the Moth.

The most usual preventives against the injury occasioned by the moth are cedar wood and tobacco leaves. A piece of the former put into a a box, if sufficiently large to emit its peculiar odour to whatever may be contained in it, will effectually preserve the cloth from injury; and it is well known, that in libraries where there are books bound with Russia leather, which is tanned with cedar, no moth or worm will corrupt. It is common to put cedar shavings and chips into boxes, &c. which answer just as well as the wood itself.

Tobacco leaves may be placed at certain intervals in the folds of a piece of wollen cloth; and it is sufficient to examine them once in six months, in order to renew the leaves if necessary.

An easy Method of preventing Moths in Furs or Woollens.

Sprinkle the furs or woollen stuffs, as well as the drawers or boxes in which they are kept, with spirits of turpentine; the unpleasant scent of which will speedily evaporate, on exposure of the stuffs to the air. Some persons place sheets of paper, moistened with spirits of turpentine, over, under, or between pieces of cloth, &c. and find it a very effectual method.

To preserve Furs, Woollens, &c.

Many woollen-drapers put bits of camphor, the size of a nutmeg, in papers, on different parts of their shelves in their shop; and as they brush their cloths every two, three, or four months, this keeps them free from moths; and this should be done in boxes where furs, &c. are put. A tallow candle is frequently put within each muff when laid by.

To keep Moths, Beetles, &c. from Clothes.

Put a piece of camphor in a linen bag, or some aromatic herbs, in the drawers, among linen or woollen clothes, and neither moth or worm will come near them.

To purify Wool infested with Insects.

The process of purification consists in putting into three pints of boiling water a pound and a half of alum, and as much cream of tartar, which are diluted in twenty-three pints more of cold water. The wool is then left immersed in this liquor during some days, after which it is washed and dried, After this operation it will no longer be subject to be attacked by insects.

Chinese Method of rendering Cloth Water-proof.

To one ounce of white wax, melted, add one quart of spirits of turpentine, which, when thoroughly mixed and cold, dip the cloth in and hang it up to dry. By this cheap and easy method, muslin, as well as the strongest cloths, will be rendered impenetrable to the hardest rains, without the pores being filled up, or any injury done, when the cloth is coloured.

New Method of cleaning Silks, Woollens, and Cottons.

The following receipt is recommended as a good method of cleaning silk, woollen, and cotton goods, without damage to the texture or colour of the same :

Grate raw potatoes to a fine pulp in clean water, and pass the liquid matter through a coarse sieve into another vessel of water ; let the mixture stand still till the fine white particles of the potatoes are precipitated ; then pour the mucilaginous liquor from the fecula, and preserve the liquor for use. The article to be cleaned should then be laid upon a linen cloth on a table, and having provided a clean sponge, dip the sponge into the potatoe liquor, and apply it to the article to be cleaned, till the dirt is perfectly separated ; then wash it in clean water several times. Two middle-sized potatoes will be sufficient for a pint of water. The white fecula will answer the purpose of tapioca, and make an useful nourishing food, with soup or milk, or serve to make starch and hair-powder. The coarse pulp, which does not pass the sieve, is of great use in cleaning worsted curtains, tapestry, carpets, or other coarse goods. The mucilaginous liquor will clean all sorts of silk, cotton, or woollen goods, without hurting or spoiling the colour ; it may be also used in cleaning oil paintings, or furniture that is soiled. Dirtied painted wainscots may be cleansed by wetting a sponge in the liquor ; then dipping it in a little fine clean sand, and afterwards rubbing the wainscot with it.

Permanent Ink for marking Linen.

Take of lunar caustic (now called *argentum nitratum*) one dram ; weak solution, or tincture of galls, two drams. The cloth must be first wetted with the following liquid, viz. salt of tartar, one ounce ; water, one ounce and an half ; and must be perfectly dry before any attempt is made to write upon it.

CHAP. XXV.

THE ART OF FARRIERY.

Hints to the Purchasers of Horses.—To purchase a horse free from blemish and imperfection, is, by experience, found to be a task more difficult and arduous than the whole art of horsemanship; and there is no kind of traffic wherein there are so many deceptions practised, as in the sale of horses. It may not be unserviceable, therefore, to put down a few short directions on this subject, by way of precaution to the unwary, and such as have been the dupes of dealers and jockies, whose business it is to impose on the credulity of the novice, by disguising every imperfection in the beast, and discovering imaginary beauties.

"I remember," says Mr. Wilson, "once to have seen a horse, which, I judged from his appearance, had been in several very indifferent hands: excessive labour had evidently been his portion, and many an ungrateful blow its reward; but, notwithstanding this, the remains of a most beautiful symmetry were yet discoverable in him. The dealer, in my presence, whipped the animal so cruelly, that I could not forbear remonstrating with him on the severity of his treatment. To which he replied, "that he had certainly the same right as other tradesmen, to set off his commodity in the most advantageous light possible; and who would be to blame," he asked, "but myself, was I not to exercise that right: but if you know not the utility of what you saw, know then," continued he, (at the same instant giving a crack with his whip, which made the poor scared creature ready to fly through the manger) "that it was to collect his scattered spirits together, in case a purchaser should drop in."—"A fig for the humanity of the world!" said I; "and is it thus every poor devil of a horse that unfortunately falls into thy hands, is to be whipped out of his skin, merely for the sake of thy advantage?" Upon which he left the stable. The horse looked behind him the moment he heard his master quit the stable. On walking up, in order to cherish him, I observed the tears rolling down his face; which operated so strongly on my affections, that I declared I would never more see an animal beaten unjustly, without punishing the offender."

There are many inconveniences arising from an immoderate use of the whip, whicd might be easily obviated, was it used rather sparingly, and with a little more lenity than it commonly is: for, instead of doing any real good, it not only makes the horse fearful of every motion you make about him, but it becomes very dangerous to go near him; as by his uneasiness, and shifting from side to side (expecting every moment a beating), he may probably throw you down, and trample you under his feet. We recollect witnessing a distressing scene, which happened to a man who made it a constant rule to whip the horses he had on sale three or four times a day, to make them show more life and spirits, as he termed it; when a horse struck him down, and almost trampled him to death.

Before you make choice of a horse, you should consider for what occupation you design him; and acquaint yourself with all the excellencies

and imperfections of these useful creatures: for, as the moderately thin-shouldered, long-backed, tall, and flat-ribbed horse, is best adapted for racing; the short-backed, small-jointed, and round-barrelled horse, for travel; the moderately large, and lean-head, a large windpipe that hangs rather loose from the fleshy pannicle, small close nostrils, high withers, and the generality of the shape strong and well knit together, for hunting; the broad-backed, full-shouldered, thick-withered, wide-breasted horse, provided his legs are short-jointed, straight, strong, and well-proportioned, for a collar; so the small horse, with a short back, small head, short-jointed, and thin legs, of a well-proportioned, and handsome shape, should be chosen for ease, and summer pleasure.

On entering the stable, in order to select a horse, the first thing necessary to be done, is, to see how he stands on his legs; and, particularly, that no person is in the stable with him; for, trust me, if there is any defect in either of those members, you will soon discover it by his shifting the position, and but just touching the ground with the toe of the leg affected.

Having satisfied yourself as to this particular, order him to be taken into some yard, or open place; but remember to be the last in the stable, or the dealer, or some of his attendants, will make it their business to fig him without your knowledge, unless you keep an attentive eye to their conduct: for these fellows being in the constant practice of it, are so expert, that one would imagine it was done by a kind of slight of hand.

The practice of figging prevails throughout the kingdom, and is so cruel in its nature, that I think, in humanity, it ought to be disused. It is done by thrusting a piece of ginger up the fundament, which makes the horse carry his tail high, and appear to greater advantage, though but for a very short time.

Every person must be aware, that the subtile fiery nature of the ginger must cause a very uncomfortable sensation in that part: for the horse cannot stand still a moment while it remains there, consequently it is unnecessarily teazing a horse, and setting but a very temporary advantage on him, just so long as the dealer can wring the money out of your purses; for the very next day, to your great chagrin, he will look five pounds worse for the experiment.

The horse being now before you in an open place, and not near any white wall, take your station about three or four paces off, in a line with his breast; observe his countenance, that it is cheerful, sprightly, and free from heaviness and gloom: That the ears are thin, small, evenly set, and terminate in a point; for if they are thick, long, too closely set to each other, and drooping, it is not only a great deformity, but such a horse will be dull, heavy, and sleepy. The face should be lean, and free from flesh; the forehead broad, and rather swelling outward; a star or blaze thereon, are considered marks of beauty and courage: but if the forehead is flat, the face in general flat and cloudy, and a baldness appear on the nose, they are deformities. If the eyes are round, black, shining, not too big, but rather protuberant, so that they move about their orbits with a quick and lively motion, and in doing it little or none of the whites appear,—they are good. But if, on the contrary; they look of a yellow cast, dull, moist, and sunk,—they are bad. The nostrils should not be so large as, upon every little effort, to occasion the muzzle to become wide, distended, and the inside redness to appear; that being a sure sign of a short wind, and weakness. The muzzle of

the nostrils should be small, and the inside free from moisture; the upper lip should not hang over the lower one, but both meet evenly together; and particularly observe, that the horse is not shallow-mouthed.

From the head, look down to the chest: if it is broad, prominent, and muscular, it denotes beauty and strength; whereas the narrow chest is an evidence of deformity and weakness; the legs, being set too close together, will interfere with the motion of each other, and thereby greatly hinder speed, cause the horse to stumble, and sometimes to fall. The thighs should be fleshy, sinewy, and moderately outward swelling; so that, upon any little strain, or movement of the body, the muscles thereof may be clearly discerned: for they are signs of strength; the contrary, of weakness. Particular care should be taken in examining the knees; that they are lean, sinewy, close-knit, and evenly proportioned: but if they appear swelled, and feel soft as if a quantity of wind had collected between the skin and flesh; or, if one knee appears larger than the other, or looks thin and bristly, the hair broken, &c.—these are true marks of a stumbler: and such a horse ought to be rejected.

In examining the pasterns, see that they are flat, lean, and free from every kind of scab, seam, and swellings. They should be strong, straight, and rather short; for a long pastern shews weakness; and such a horse cannot perform a long journey without tiring.

Nothing is more essentially necessary to be observed in the purchasing a horse, than the formation of the hoofs, which are the grand foundation of the whole mechanism of the animal; for, if they are bad, the superstructure, however finely proportioned, cannot possibly be good.

The hoofs should be smooth, tough, rather long, deep at the heel, and either black or dark brown: the former are the best proof against the effects of hard and bad roads. The white hoofs are tender, and subject to foundering. The light brown ones are brittle, consequently will not carry a shoe well. A round hoof proceeds from contraction, and the flat ones shew foundering.

If the hair on the coronet, or top of the hoof, lies smooth, close, and the flesh even therewith, it is perfect; but if the hair on that part looks thin, bristly, with little scales, or scabs on the skin, and the flesh swelling over the hoof, I would advise you not to buy such a horse, as they are the forerunners of ring-bones, crown-scabs, quittor-bones, &c.

Be particularly careful in examining the bottom of the feet; placing your thumb on the frog, compress it rather sharply, in order to discover any defect that might be there;—that they are large, spreading, open, and sound. I believe, I need not remind you, that the spongy, running, and decayed frogs are to be rejected.

You are now to stand about three paces off, in a line with the horse's shoulder, and take a side view of him: the neck should be small, and rather short than long; and particularly observe, that no swelling appears on the setting on of the head. The shoulders should lie rather backward, and come round with a good sweep, and rise well up to the withers.

A horse low in the shoulders will be continually getting the saddle on his neck, unless a crupper is affixed to it. This, beside being very ungraceful, will cause him to stumble, and very probably to break down. The tail should stand rather high, flat, and bending a little inward; which, if the horse has a good buttock, it will do: but on a

bad buttock, a hog or goose rump, a tail cannot stand well—They are objectionable deformities.

You are now to take a view of the hind parts, standing at a convenient distance from the horse, that you may more advantageously see that the hips are broad, round, and even; also that the hind legs are lean, flat, and sinewy. Be careful that they are not fat or swelled, and that one elbow of the hock is not larger than the other; that no seams or scars appear thereon; and that he is not bow-legged.

Various are the arts used by dealers, to prevent your discovering the true age of a horse by his teeth. It is therefore useless to write a long dissertation on that subject, as it would serve to perplex my reader, rather than to enlighten his judgment.

The shortest and most certain method to judge whether a horse is young or old is this:—Turn back both lips; if the teeth are small, white, glossy, and fit evenly together,—he is young; but if they are large, long, yellow, irregularly set, and the top row project over the bottom, the tusks yellow, or of a blackish colour,—he is old.

Having finished your examination of the horse, see him walk and trot in hand; and let not the groom haul his head about, nor be too free with his whip; but that he leads him carelessly by the extreme end of the halter or bridle, as, by that means you will discover any defect that might possibly be in the joints, or if he be a stumbler.

Observe the motion of the legs: that the near fore leg, and the far hind leg, or the far fore leg, and the near hind leg, move, or shoot, at one and the same time; and that the hind legs do not obstruct the motion of the fore ones, but that all act in unison.

Order the groom to take his back, and, standing behind him, see how he walks: that he carries his head even, and the bit level in his mouth; that he does not bear down, nor pull on either side; but walks and trots straight, lifting his legs well off the ground with boldness, at the same time managing all smoothly.

If a horse makes a clattering noise in his gallop, he interferes; that is, by treading too long, or making too much play with the hind leg, he strikes the toes thereof against the corners of the shoes before, which occasions a very disagreeable noise.

It is a natural imperfection, occasioned by uneven proportion; for, on critically examining such a horse, you will find him not only low in the shoulders, which causes weakness in the fore legs, but that the hind ones will be longest.

A horse, to gallop well, should lead off with his far fore foot, and lift his feet well off the ground, at the same time not raising them too high; and, in spreading his fore legs, he should follow even and lightly with the hind ones, without cutting under the knee, or injuring the back sinews of the fore ones.

Having seen the different paces of the horse, and formed a good opinion of him, it will not be unreasonable to request, particularly if you are the least known to the dealer of whom you are about to purchase, that you may be permitted to ride him a mile or two; and should he object to such a proposal, you would be warranted in forming a very unfavourable judgment of the horse, as well as of himself. If he permits you to ride the horse, when you are mounted, let him go his own pace, holding a loose rein: you will then have a better opportunity of knowing whether he be a stumbler; or whether he is sure-footed, and

goes forward boldly, without halting or starting at every object which presents itself; at the same time, that he is not heavy or dull; they both have their bad effects, and ought to be rejected for these reasons:— The startlish horse, by his timidity, exposes you every moment to imminent danger; whilst, on the other other hand, the sleepy or sluggish horse provokes you every moment.

Observations on Breeding.

If you would have a colt free from imperfection, be careful that there is none in either the mare or stallion; but that they are youthful, sound, and of a good breed. As to colour, it is of little consequence, as I conceive a good horse cannot well be of a bad colour; but endeavour to let their marks be as much alike as possible. The mare should be fourteen, and the stallion fifteen hands high; and not more than six or seven, or less than four years old, when they are brought together.

A mare will bring foals at three years old; but they will be stronger and better shaped at four.

I would advise you not to breed in fenny or swampy grounds; the grass on such land being so gross, will breed humours in the blood.

The land being also too moist, will soften the hoofs, and make them grow larger than nature intended them; by which means a light carcassed colt would be completely spoiled; the gross feeding alone would make his body heavier than his limbs could well sustain.

The hoofs being grown too large and heavy, will cause the legs to swell; so that, at the best, the motion of such a colt would not be near so good as that of a Flanders mare.

Supposing for a moment you would have a colt to do you credit as well as service, let the situation for breeding be a stony or gravelly soil, abounding with little hills; for they are of most excellent use for the colts to play on, and in which they much delight; it will make their hoofs tough, their legs well knit and sinewy; and the grass on which they feed not being too gross or luxuriant, they will be well-proportioned, and of exquisite symmetry.

If you have several mares with foal at one time, remember to keep them separate when they have foaled; as, otherwise, one or other of the young, by going to each other's dams, might probably get a kick that would lame him for ever after.

Colts may be weaned at seven or twelve months; as you may then give them oats, bran, and short sweet hay. Your oats may be cracked in a mill, or moistened with boiling water; but be careful you do not give it them too warm. Peas and beans are to be avoided: they are too strong, and of a heating quality.

In the winter season they should be taken into the stable entirely, and made familiar to you, by rubbing them often with a horsehair cloth, leading them to water, lifting up and setting down their feet; by which means you will find it facilitate the breaking and taming them considerably. And here I must caution you against letting servants teach them bad tricks, as kicking, biting, and rearing on their hind feet; for if they do, it will be a difficult task to break them of such vicious habits.

On Training Colts.

At two or three years old a colt should be trained; and if he is anywise gentle, take a strong snaffle bridle, rub a little honey on the bit,

and let him receive it at his mouth. Take him to some field, and exercise him in the ring for the space of an hour, several mornings together; and if you find that he is tractable, you may then offer him the saddle; but take care you do not frighten him: this may be prevented by hanging the saddle in a situation that he may always see and smell it when the groom takes him in and out of the stable to water, &c.

When you have got the saddle on his back, make the girths fast gradually; then take it off, and place it on again, two or three times, so that he may become acquainted with it; and with what he seems most shy or fearful, with that make him familiar.

Having bridled and saddled him, let him stand about an hour in the stable; then lead him into some field or open place; and, in order to inure him to the saddle, clap it with your hand, rub the stirrups against his side, sway upon them, &c. By frequently tutoring him in this manner, he will soon understand his business.

When you have taught him to walk and trot quietly with the saddle and bridle, you may venture to take his back, not too suddenly, but by degrees; first putting your foot into the stirrup (having some person to assist you, and to govern his head), and raising yourself gradually, till he will suffer you to stand with your whole weight in the stirrup. If he shrinks, and is fearful, do not mount, but trot him in the ring again, using all gentleness and cherishings with the voice; then try him again; and if he is willing to receive you, settle yourself in the seat, and take the stirrups. Be careful that your tackle is strong and good; for, should he spring a girth or crupper, he may roll you in the dirt.

When you are properly settled, and have received the stirrups, the person who governs his head must lead him forward about a dozen yards; then make much of him, and, if he is quiet, dismount and remount alternately; teaching him to go forward, and stop upon the restraint of the bridle hand.

Having taught him to walk and trot boldly forward, without startling at every object he sees, you may then venture to canter and gallop. By exercising him in this manner twice every day, he will soon become perfect in all his paces; and you will not regret the trouble you had in teaching him.

Directions for Riding.

If you would acquire the art of riding gracefully, and at ease, in which most gentlemen take much pleasure, apply yourself to the following short directions, and you will soon attain it.

A snaffle bridle is best for the purpose of learning to ride.

When the horse is brought out of the stable, teach him to stand steady whilst you mount; at first holding a rein in each hand, till you are acquainted with the proper use of them, and can command your horse with the bridle hand only.

You must sit firm in the saddle; the body carried upright, and the shoulders back.

The arms are to be kept close and firm to the sides; the elbows level, and in a line with the back; the knees turned in, and pressed against the saddle, and a little bent.

The legs should be carried straight down, the ball of the foot resting in the stirrups, so that you can just bear upon them, to command your own body and the motion of the horse.

Being thus seated, walk him round a circle, then trot, and lastly

canter; always keeping the outside hand elevated about three inches higher than the inside one, which must be held shorter, and kept firm to the side.

The inside leg must be compressed close to the horse's side, and the outside one carried a little forward, and projecting so as not to touch with it.

The stirrups should neither be too long nor too short; nor should persons learning to ride ever use them till they can ride well without: by this method the cavalry are taught, and an excellent practice it is.

When you have trotted about half a dozen times round the circle, change hands, to ease yourself and horse, by riding across it in the shape of an S.

Having obtained a knowledge of the use of the reins, in the changing of hands, and various turns, learn to govern your horse with the bridle hand alone, which will at first seem rather awkward, but by practice you will soon get the better of it.

I have but this to add upon the subject, that if you conform to these directions, and exercise yourself in them for a fortnight or three weeks, it will so settle your body and limbs to, and acquaint you with the different paces and general motion of the horse, that you will not only ride gracefully, but considerably more at ease ever after.

Directions for Using a Horse on a Journey.

Before you undertake any long journey, it is necessary to be careful that your horse is not newly taken from grass. He should be kept in the stable a week, at least, previous to your setting out; because he will then be cleansed, in some degree, of the foulness which grazing brings on, especially if he has been at grass for any length of time; in which case a gentle purge may be necessary to assist nature in carrying it off. He will then have nothing but solid food in him, and therefore be able to pursue your intended journey with spirit, and without tiring.

When he is brought out of the stable, examine the girths and stirrup leathers; that they are strong and good, that his shoes are tight, and that he is not curbed too high, in order that as few obstructions as possible may occur on the road; for, on these things, trivial as they appear, depend much of the security, as well as the pleasure of your journey.

If all is right, make the horse stand firm and immoveable till you are properly seated, and have adjusted your dress.

When you would have your horse go forward, do not let him feel whip or spur immediately, but convey your meaning to him by some kind of signal, as by pressing the calves of your legs against his sides; for he is an animal so docile and governable, provided you use gentle means, that he will obey if he does but understand you.

Ride moderately the first mile or two, that his blood may not become warm within him too suddenly: you may then quicken his speed by degrees, according as your occasions, or the importance of your business requires, so as not to overheat your horse, because the violence of such exercise will eventually set his blood a boiling in his veins; and the velocity thereof will be so great, that fevers, surfeits, eruptions of the skin, &c. will inevitably be the consequence.

You may safely permit your horse to wash his mouth at every little stream, or watering place on the road; as it will greatly refresh him,

and enable him to proceed with spirit, provided you do not let him drink too much; therefore two or three gulps or swallows may be allowed him at any time. I would advise you always to contrive to let your horse drink his fill, if he is not over warm, about a mile from the town at which you intend to stop; as the water will then warm in his stomach by the time you arrive at the inn, which is far preferable to the common mode of watering in the stable.

After you have finished the day's journey, see that your horse is put into a warm stable, and is well cleaned, clothed, and washed, that the hoofs are scraped out, and that he has plenty of good sweet hay; always avoiding every kind of stuffing composed of cow-dung, clay, tar, &c. which is kept by the ostler, at almost every inn, in town and country—They are of too cold a nature.

It is also a good method, to moisten a sufficient quantity of bran, with any kind of grease, over the fire, in a pipkin; then to put a ball of it into each foot, and to cover it with a piece of coarse cloth or tow, making it fast with a couple of splints.

On Stable Management.

Particular regard should be had to the situation and materials of which a stable is built: it should not be built with stone, as in damp or wet weather it is apt to sweat; and the continual evaporation of moisture through the walls, will make it very unhealthy for the residence of horses; insomuch that disease, and sometimes death, must unavoidably be the consequence.

A stable should stand detached from all other buildings, and no cess-pool, gutter, or sink should be near it. Nothing can be more wholesome than a brick-built stable; wood may answer very well, but brick is much warmer.

The rack should be placed in such a manner, that no hay dust can fall on the horse's head: the pavement should not be raised so high at the manger as is common, but just so that the water may drain off; for by raising the floor too much at the head, the principal weight of the horse is thrown on the hinder legs, which will cause them to swell.

The refuse of potatoes, where they are plentiful, washed clean, are excellent for horses; and may be given occasionally, by way of change, instead of corn; about a gallon at one time: they are very wholesome food; and horses that feed on them soon get into condition.

Carrots are not good for horses: they do not digest kindly, therefore are to be rejected. Turnips are very good, if given in small quantities.

The way to get a horse into condition, is not by continually filling his rack with hay, and cramming him with corn, as some people suppose; but by observing regularity in giving him his food, frequently, and in small quantities. The hay should be tied up hard, in small pottles, or trusses, by which means there will be less waste. You may give him now and then some sweet grains, mixing a handful of salt in them, which will cleanse the intestines and destroy worms.

On the choice of a groom, the perfection or imperfection of a horse in a great measure depends.

A man that is of dissolute, debauched, or irregular life, or of ferocious habits, is by no means a proper person for a groom: such a man will beat your horse in your absence; and whatever defect you discover

in your horse, should not be attributed to him, but to the mismanagement of the groom.

Let the man, therefore, whom you intend for this occupation be thoroughly acquainted with his business, and a complete horseman; let him be also steady, mild, and gentle-tempered; as your horse will be most likely to thrive and become useful under the care of such a man.

On the Gelding of Horses.

It is seldom that the gelding of a colt is attended with any bad accident; it is a very simple and easy operation, so that any country farrier may do it safely, by cauterizing the extremities, and filling the scrotum with salt. But this method will not answer the purpose in a full-grown horse, especially if either of the testicles are bruised or hurt; it will then require the assistance of a skilful operator.

The horse being first cast on a soft place, open the scrotum on each side, turn out the genitals, and with a well waxed thread tie the string to stop the blood, when you may with a sharp knife cut them off.

The wound may be dressed with pledgets dipped in spirits of wine and camphor; or with the green ointment alone.

If an inflammation should ensue, and the sheath and belly swell, it must be treated with warm fomentations, and the horse kept rather sparingly; making his water milk-warm, in which should be sprinkled a little oatmeal; or give him thin barley-water to drink.

On Docking Horses.

The real cause of so many horses dying after the operation of docking is the want of skill, as also proper instruments to do it with. I once saw a horse docked in the country, by laying the tail on what is called a bill-hook, and making the blow upon it with a mallet; which is very wrong, as the tendons must be very much bruised by making the blow upon the tail.

The only instrument applicable to this operation is a proper docking knife, which should be passed through a joint, if possible, while the tail lies on the block.

The searing iron should not be flaming hot when you apply it; because the sparks which fly from it will cause an intolerable pain, which falls down to the fundament and sheath, and will probably bring away the burnt part along with it; in which case, bleeding will ensue; you will then be obliged to apply it again.

The searing iron should be well polished, and rubbed very clean with a woollen cloth before it is used. When the scar is got off, wash the part with lime-water.

On Nicking Horses.

When the horse is cast on a soft place, with a sharp knife, cut three nicks under the tail; in order that the depressing muscles may be unstrung, and the elevating ones act alone. A piece of tow dipped in powdered rosin and spirits of wine, may be placed between each nick; wrapping a bandage of the same round the whole of the tail, to prevent the application from falling out.

The best method which has been yet contrived to keep the tail in an erect posture, after nicking, is a pulley with a weight affixed to the end of the cord.

Having finished these observations in as plain a manner, and with as few technical terms as possible; we shall now treat on the various diseases incident to that useful creature, the horse; and prescribe the best and most easily obtained remedies.

Bleeding and Purging, the farrier always considers a striking proof of his consequence, and a never-failing mark of his infallibility; but it never can be tooo much discouraged, and in fact ought by no means to be countenanced, or indeed permitted. If no particular plethora or fulness appears, to render large evacuations necessary, three pints will prove sufficient for a slender or delicate subject; two quarts for the more advanced in strength or size; but from the very large and strong, or remarkably foul horses, may be safely drawn full five pints. However, these distinctions should be carefully made by measure, to avoid the inconvenience and danger of too much relaxing the whole system; an impropriety in conduct that may not be so easily remedied as imagined. After this evacuation, let the same regular system of food, and gentle exercise be continued for three clear days; and on the fourth prepare his body for the physic intended to be taken on the following morning, by giving him in the course of the day three mashes of equal parts of bran and oats, scalded with boiling water, and given, at a proper degree of warmth, morning, noon, and night; putting on the necessary body clothes, at the time of giving the first mash, to prevent the least hazard of cold from the relaxation of either body or pores. In the morning give one of the following purging balls, of which four different proportions are specified, and calculated for the horses before mentioned, in respect to strength, size, and constitution. But as we shall, in the course of the work, have occasion to introduce references to these cathartic balls, under the heads of various diseases, it will be more convenient to distinguish them by numbers; and, beginning with the weakest, the reference need only be made to the number in future, without a repetition of the ingredients.

Purging Ball, No. 1.—Take of succotrine aloes one ounce; India rhubarb two drachms; jalap and cream of tartar each one drachm; ginger (in powder) two scruples; essential oil of cloves and aniseed each twenty drops; syrup of buckthorn a sufficient quantity to form the ball.

No. 2.—Take of succotrine aloes ten drachms; of rhubarb, jalap, and ginger, each two drachms; cream of tartar three drachms, and syrup of buckthorn to make the ball.

No. 3.—Take Barbadoes aloes nine drachms; jalap, castile soap, and cream of tartar, of each two drachms; diagrydium and ginger (in powder) each a drachm; syrup of buckthorn sufficient to make the ball.

No. 4.—Take Barbadoes aloes ten drachms; castile soap and jalap (in powder) of each half an ounce; cream of tartar and ginger each two drachms; oil of aniseed forty drops; of cloves twenty drops; which form into a ball with syrup of roses or buckthorn.

It is almost unnecessary to observe these balls are gradually increased in their purgative qualities, so as to be selected by the judgment of the reader, according to the state of strength and foulness the subject may be in; and are so carefully guarded with warm aromatics, that the operation will (by a strict adherence to the following rules) in general proceed without the least alarm or danger. The ball being given

early in the morning, let it be washed down with a quart of water slightly warm, to take off the nausea as much as possible; leave in his rack a little sweet hay; and, in about three hours after, give a warm mash of scalded bran, containing one fourth of oats; upon which let the water be poured boiling hot, and stand a proper time to cool, before it is put into the manger; as, by placing it there too hot, the fumes produce an antipathy which the horse does not easily get over; on the contrary, by touching the mash, and being burnt, will not be prevailed upon to attempt it in future. In case of a fixed aversion to mashes, a feed of bran may be given at the stated periods, in which may be mixed one quart of ground oatmeal. Water proportionally warm may be given him to the quantity of half a pail thrice in the day; and let his mash be repeated twice that day also, and early on the following morning, about which time the physic may be expected to begin its operation; but if the mash should be refused, a pail of warm water may be substituted; and in two hours after the horse (well clothed) walked out for half an hour at least. Frequent supplies of warm water must be given, and two other mashes at their proper times; by no means omitting to take him out, and walk him gently twice or thrice in the course of the day, But, as purgatives administered to quadrupeds of this description cannot, from the great continuation of the intestinal canal, be expected to commence their operation in less than twenty-four hours, no hurrying or forcing methods must be taken to agitate the animal, or produce preternatural effects. So soon as the medicine begins to operate, kindly and patiently assist the work by the means before-mentioned, at stated periods, or at such times as the appetite will permit them to be taken; continuing the mashes no longer than the physic is said to be set, or (in other words) the excrements become firm, and resume their original form.

Six clear days should be allowed between the first and second dose, and the same space between the second and third. The entire course being regularly gone through, it will undoubtedly remove every degree of foulness, resulting from full feeding at grass: and, unless some palpable defect or latent obstacle indicates the contrary, he will (in little more than a fortnight) by his flesh, coat, and spirits, prove his ability to undertake any moderate chase in which his rider may be inclined to engage.

A Purging Drink.—Take senna two ounces; infuse in a pint of boiling water two hours, with three drachms of salt of tartar; pour off and dissolve in it four ounces of Glauber salts, and two or three drachms of cream of tartar.

When the rectum is plugged up so as to prevent the passing of the pipe for the injection of a glyster, which should be given immediately with a large bag and pipe procured for the purpose, and repeated if necessary; making not the least doubt but this lubrication and stimulus will remove all obstructions, and afford every advantage that can be obtained from the favourite and long standing practice of raking.

To prepare a Glyster,—Take of camomile flowers, sweet fennel, and coriander seeds bruised, of each one ounce; carraway seeds half an ounce; boil in two quarts of water till reduced to three pints; then strain, and add for solution, while hot, of Epsom salts two ounces; and, when nearly cool enough to administer, add of olive oil, and tincture of senna, commonly called Daffy's elixir, of each a quarter of a pint

On the contrary, where the constitutional stamina does not prove so strong as imagined, the bowels in a weaker state than expected, or the medicines are found to irritate or purge more than is requisite or desired; and the physic does not set at the usual time (the horse being consequently low, and off his appetite), let the following cordial restringent ball be prepared and given immediately, repeating it in six or eight hours if necessary.

Take mithridate one ounce, Armenian bole, gum arabic, and prepared chalk (in fine powder), each half an ounce; ginger (in powder) two drachms; syrup of diacodium, quantity sufficient to make a ball.

In three hours after let the following restringent mash be given, properly prepared and kept occasionally stirring when over the fire, to prevent its bnrning: or this may be given, if necessary, without the ball, where the operation has not been so violent as to require both.

Restringent Mash.—Take two pounds of rice, and half an ounce of cinnamon, bruised to a gross powder, and tied up loose in a piece of linen (fine enough to prevent its passing through); boil in five quarts of water till reduced to the consistence of a mash; take out the cinnamon, and stir in a quart of ground oatmeal, and let it be placed in the manger when of a proper warmth. This may be repeated if necessary.

Splents.—These are hard excrescences of different shapes and sizes on the shank bone, which often disappear of themselves. They are not dangerous but when situated near the joints, or appear very large upon the back part of the bone, and press against the back sinew. They are an enlargement of the periosteum (or membrane covering the bone), by an original rupture of the small vessels, and the extravasated fluid collected and become indurated by time.

In either case the only expectation of cure without anxiety and difficulty, is to be careful in observing the appearances, in their earliest state; and then seeing that frequent friction is used for a considerable time, twice every day, with the utmost force of the operator's hands, letting the part be well moistened, after each time of rubbing, with a proportion of the following liniment, leaving a pledget of tow wet with the same, bound on pretty firm with two yards of wide tape as a roller.

Take camphorated spirits of wine, and spirits of turpentine, of each four ounces (a quarter of a pint). Mix together.

Or,—Oil of origanum and spirits of turpentine, each half an ounce; camphorated spirits of wine, two ounces.—Mix.

When this plan has been persevered in for ten days or a fortnight, you will then be able to judge whether any perceptible advantage has been obtained from the force of these powerful repellents: if not, procure two ounces of the strongest mercurial ointment, and let the size of a hazel nut be well rubbed in upon the part affected, every night and morning, till the whole is consumed, using the roller each night, and taking it off in the morning. If this does not succeed, the best and most speedy method will be the immediate extirpation, by making a longitudinal incision through the integuments, dissecting and extracting the substance, completing the cure by taking up a couple of stitches, and treating it as a superficial wound; for which directions will be found under that head.

Spavins.—Of these there are two kinds, very distinctly explained by most authors on the subject, and justly denominated a blood and bone

spavin. They both take their seats in nearly the same situation, and proceed from the following causes—a blood spavin is a preternatural enlargement of the vein running on the inside the hough, and by the accumulated fluid forms a swelling that is pliant to the touch, submitting to pressure, becoming, in the course of time, productive of lameness. These appearances, were they attended to in their infancy, would (as observed in the preceding article) immediately submit to a frequent application of the following embrocation; rubbing in about two table spoonfuls twice every day, and keeping on (when in the stable) a pledget of tow, wet with the same, and confined with an elbow bandage; that is, the elbow part of an old waistcoat sleeve, opened and furnished with tape strings, at equal distances, to confine it upon the part affected.

Take of strong white wine vinegar four ounces; camphorated spirits of wine three ounces; extract of saturn, commonly called Goulard's extract, one ounce; shake well together at every time of using.

In almost all cases of short standing the cause of complaint will submit to the power of these constant applications, that, by their action upon the solids, so restore their elasticity and contract their circumference, as to repel the internal expanding fluid, and reduce the vein to its natural and original size. But where the defect is of long standing, and will not submit to this mode of treatment (the attempt having been sufficiently persevered in to ensure a fair probability of success), the following had better be adopted.

Take of cantharides (in powder) one drachm and a half; of olive oil two ounces.—Mix together. And let this be gradually rubbed upon the part till absorbed by the seat of disease; then place over it a piece of flannel, and fasten on with the elbow-bandage as before described. In every eight-and-forty hours repeat this operation for a week (with the same proportion), which has been attended with certain success in a multiplicity of cases, particularly in the metropolis of Ireland, where the most eminent practitioners (and very able there are) prefer it to our general method. The great advantage resulting from this kind of blister is its immediate stimulus upon the parts, from which is derived a very speedy and plentiful discharge. The hair is raised up, and becomes what is termed pen-feathered, during the efflux of serum, in large proportion; which, subsiding, forms a kind of scurf, and may be all brought away in a few days by washing two or three times with soap and water; leaving no scar or trace of external application behind. And surely this method, justified by success and experience, must be preferable to the long-standing opinion of instrumental extirpation. As for instance, an incision is to be made through the skin, of sufficient length to admit of the vein's being taken up, above and below the enlargement, by passing a crooked needle, furnished with a wax thread, underneath the vein, and making the ligatures at the parts most applicable to the extirpation intended. Should any inflammation or extreme swelling attend the parts after operation, warm fomentations and mild poultices must be made use of till they subside; after which the wound must be treated with digestives till the exuberance is sloughed off with the dressings, and the cicatrization, or skinning over, is accomplished, as in the case of abscesses and wounds, which must always be treated by the professional farrier.

Every degree of information, observation, and experimental investigation, defines a bone spavin to be exactly in a greater degree behind what a splent is acknowledged to be before; formed nearly by the same means, fed nearly in the same manner, differing only in its critical situation; which, from a contiguity to the joints, and ligamentary appendages, become so much the more an object of concern and attention, to avoid the certain impediment of lameness, which will in time inevitably ensue, if not prevented by reduction or extirpation.

Windgalls—Are these prominences situate on both sides the tendons (commonly called the back sinews) above the fetlock joints on the fore-legs, and not unfrequently upon the hind-legs likewise. They are much larger on some horses than others, and as they never appear but upon those that have been constantly worked too young, or proportionally overworked when older, the cause will be the more readily explained. For the tendons, by their perpetual action in constant labour, are so preternaturally extended, that some of the fine and delicate fibres of which the aggregate is composed, are, by such extension, actually ruptured or broken; from the mouths of which (minute as they are) ooze a very trifling portion of serum, or fluid, which, when extravasated, forms a gelatinous substance; and, combining itself with the included air, becomes, to external appearance, a kind of bladder between the tendon and integuments.

CHAP. XXVI.

POLITICAL ECONOMY, OR THE NATURE AND CAUSES OF THE WEALTH AND POVERTY OF NATIONS.

The labour of a nation is the original source of its supplies, which consist in the produce of that labour, or what is purchased with it. The productive power of labour, or its capacity of yielding supplies, may be improved. The principal cause of this improvement is the division of labour, or distributing the labour necessary to produce any commodity among several hands. The general effect of this division may be understood, from observing its operation in particular manufactures. In pin-making, ten men, by taking each his distinct part of the labour, can make 48,000, or 4,800 to one man; whereas a man not brought up to the business would certainly not be able to make 20 pins in a day. The division of labour cannot be carried so far in agriculture as manufactures. The benefit of the division of labour arises from the improved skill and dexterity of workmen; from the saving of time commonly lost in passing from one employment to another; and from the use of machines to facilitate and abridge labour, which are either owing to the ingenuity of workmen wholly employed in one operation, or to that of artificers or philosophers who have made one branch of labour or science their occupation. The increase of productions by the

division of labour increases wealth, as it gives every individual a greater power of communicating, and therefore of procuring, articles of utility or convenience.

The division of labour arises, by slow degrees, from a propensity in human nature to barter and exchange. Men obtain supplies in one kind by communicating them in another. One man, ingenious or dexterous in any particular article, exchanges the productions of his own labour for those of others; and finding this the best way of supplying his wants, applies himself wholly to one kind of employment. Without this distribution of labour, all having the same necessary work to do, none would have an opportunity of displaying particular talents, nor would the labours of one man be useful to another.

The division of labour is limited by the extent of the power of exchange, or the market. In small towns there cannot be so many distinct trades as in large ones. Water-carriage, by extending the market, encourages industry. Hence the sea-coasts, or borders of rivers, are first civilized; and many countries continue barbarous for want of rivers or canals.

In the first simple forms of barter, exchange must be limited by the mutual wants of the persons concerned: unless each party needed the superfluities of the other, there could be no commerce. To remedy this inconvenience, every person, besides the produce of his own labour, would endeavour to keep by him such commodities as would be most likely to be generally received in exchange: thus cattle, fish, hides, shells, have been made common instruments of commerce. At length metals were generally adopted for this purpose, partly because they are exceedingly durable, but principally because they are capable of being divided without loss, and thus conveniently proportioned to any quantity of commodity. Iron, copper, gold, and silver, have been used as money, first in rude bars, afterwards in stamped pieces to prevent adulteration, then in coin to save the trouble of weighing. Money was received by weight, not by tale, till avarice and injustice raised the nominal above the real value.

The value of any thing, in exchange, is its power to purchase other goods. The real measure of the value of all commodities is labour. Every man is rich or poor, according to the quantity of the produce of labour which he can purchase. The exchangeable value of any commodity is therefore equal to the quantity of labour which it will enable the owner to command. Money varies in value, according to the degree of difficulty with which it is obtained, and from other causes, and cannot therefore be a certain measure of the value of other things; but equal quantities of labour must at all times be of equal value to the labourer; labour therefore will be an invariable measure of value. Labour, as well as other commodities, has a real and a nominal price; the real, the quantity of real goods which is given for it; the nominal, the sum of money paid for it. Money is an exact measure of the value of goods at the same time and place; but at different times and places it varies. Corn is a good measure of the value of commodities from century to century, because it will nearly command equal quantities of labour from century to century; but from year to year it varies on account of the fluctuation of the seasons: nothing but labour is an uniform measure of real value. The nominal value of any commodity is the quantity of gold or silver for which it is sold, without regard to

the denomination of the coin. Six shillings and eight pence was the same money price in the time of Edward II. with a pound sterling at present, containing as much pure silver.

The price of every commodity may be resolved into one or more of these three parts: the wages paid for the labour spent upon it, the profit allowed for the stock employed in carrying on the manufacture, and the rent of land. Corn, flour, flax, and most other articles, resolve their price into these three parts: that of fish commonly arises only from two of them, wages and profit of stock. The price of all the commodities which compose the whole annual produce of the labour of every country taken complexly may be thus resolved. All revenue is derived from wages, profit, or rent. The revenue arising from interest, is stock lent to be employed by another, and is therefore only a division of profit between the borrower and lender. Rent and profit, and wages and profit, are sometimes confounded by those who farm their own estates.

In every society or neighbourhood there are average rates of wages, profit, and rent, which may be called the natural rate. The natural price of any commodity is that which is just sufficient to pay the rent of land, wages of labour, and profits of stock, according to the natural rates. The actual or market price often differs from the natural price; being regulated by the proportion of supply and demand. When the market price sinks and continues below the natural price, either rent, wages, or profit, must be lowered; when it rises, one or more of these will rise. In those articles which do not afford regular produce according to labour, as grain, &c. the market price must be subject to frequent variations. The market price is often kept up above the natural price, by concealing the increase of demand, by preserving secrets in manufactures, by monopolizing the sale, and by all laws which limit competition in particular employments. It seldom continues long below the natural price; for, in this case, the seller feeling the loss, will soon lessen the supplies and raise the demand.

The natural price of commodities varies according to the different natural rates of wages, profit, or rent, each of which are fluctuating. The causes of the variations in each are next to be considered.

The wages of labour depend upon the contract made between the labourer and the owner of stock, who employs him. In forming this contract, the employers have the advantage of the labourers; the latter not being able so easily to enter into combinations, or live without labour. Masters are always in a sort of tacit combination not to raise the wages of labour. Labourers seldom gain any thing, either by offensive or defensive combinations. But there is a certain rate, below which it seems impossible to reduce wages for any considerable time; it must always be sufficient for the maintenance of the individual, with some surplus for his family. Wages will naturally rise with an increasing demand for workmen, which will happen when masters increase in revenue and stock, or the surplus of what is necessary for their own maintenance and employment This increase of revenue and stock is the increase of national wealth. In wealthy countries not increasing, but stationary, the number of labourers is generally too great, and a competition on their side reduces the price of labour, as in China. Wages in Great Britain are higher than is barely necessary; for summer wages are generally highest, though winter expences are greatest; the lowest wages are therefore adequate to the highest necessary ex-

pences. Wages do not fluctuate with the price of provisions; they are therefore adequate to the highest price of them. Wages vary, in different places, much more than the price of provision, and are often lowest when that price is highest. Wages have greatly increased, not only nominally but really, during the present century. For while the price of labour has been raised, grain has been somewhat cheaper than in the last century till the year 1764, since which time a long series of unfruitful years have raised the price: several other kinds of vegetables and coarse clothing are also cheaper; so much as to balance the advance upon sundry articles by taxation. The luxuries among the common people sufficiently prove this. This improvement in the circumstances of labourers is a great advantage. It increases personal happiness, promotes matrimony and population, and encourages industry by increasing their strength and chearfulness, and giving them hopes of bettering their condition. It has been observed, that the poor do more work in cheap than in dear years.

The profit of stock is lowered by the general increase of stock, in consequence of the increasing competition it occasions. Profits are exceedingly variable, from the variations of demand, the circumstances of purchasers, and many accidental causes. No certain knowledge of their average can be obtained. The best idea of them may be formed from the state of interest, which will bear a proportion to the profits to be made from the borrowed stock, and may perhaps generally be reckoned to be one half of the profits; it being a general remark, that double interest is moderate or usual profit. But interest is no measure of the flourishing or declining state of a nation; for a diminution of profit, and consequently of interest, may be the consequence of increasing stock and a prosperous trade; or, on the other hand, profits may be so great, and new opportunities of employing stock may occur in the course of trade so exceedingly advantageous, that it may be worth while to give very high interest for money.

In the same society or neighbourhood the advantages and disadvantages of different employments of labour or stock must be equal, or tending to equality; else one branch would be overstocked and another deserted. The circumstances which tend to produce this equality, by making up for a smaller pecuniary gain in some employments, and counterbalancing a greater in others, are these: the agreeableness or disagreeableness of the employment; the easiness and cheapness, or the difficulty and expensiveness of learning them; the constancy or inconstancy of employment in them; the small or great trust reposed in those who practise them; and the probability or improbability of success in them. These circumstances however can only operate towards producing an equality in the whole of the advantages or disadvantages of different employments, when the employments are well known and long established, when there is no extraordinary increase or defect of demand, and where one employment is followed solely or principally.—Other inequalities in the advantages or disadvantages of different kinds of employments of labour or stock arise from the restrictions or encouragements of law. Of the former kind are the exclusive privileges of corporate bodies; such as, requiring that those who follow any trade should have served an apprenticeship in the town under a master properly qualified, allowing each master only a certain number of apprentices, and obliging each apprentice to serve a certain number of years,

Of the latter kind are such establishments as make provision for the education of youth in particular employments. These inequalities are farther increased by such regulations as obstruct the free circulation of labour and stock from employment to employment, and from place to place: the former is done by the laws relating to apprenticeships, the latter by corporations, and by the poor-laws, which make it difficult for the poor to remove and exercise their industry in a parish to which they do not belong. This is a great infringement of natural liberty, and one principal cause of the very unequal prices of labour in different places. Laws to fix the rates of wages, or prices of goods, are wholly unnecessary: the natural operation of plenty or scarcity of work or demand will sufficiently regulate them.

The third constituent part of the value of commodities is rent of land. It is claimed from the landlord, on account of his property in the land, and the stock he has laid out upon it. Rent arises from that part of the price of produce, which is more than sufficient to defray the price of labour, and the profit of stock upon the farm. It will therefore be high or low, according to the price of produce. Some products of land always afford rent; and some do not always afford it. Land always produces more corn and pasture than is sufficient to maintain the labour and replace the stock employed upon it. The situation of land near large towns increases the rent, by diminishing the labour necessary for conveying its produce to market. Inland navigations and good roads have the same effect. Corn fields produce more food than pasture, and would therefore be more profitable, if the same weight of food from each was of equal price. In the beginning of agriculture, corn is more scarce than cattle, because these are fed on uncultivated wilds; but the increase of cultivation throws the balance in favour of corn. There it becomes necessary to raise the price of cattle, till they will yield the landlord as much rent, and the farmer as much profit, as they might have gained by employing their improved land in the growth of grain: this, at the same time, raises the rents and profits of unimproved pasture. In some situations, pasture ground is much more profitable than corn, particularly near large towns. Where there is not sufficient extent of land to grow both grass and corn, it is eligible to grow the bulkier commodities, and purchase grain, as was the case in ancient Italy, and is at present in Holland. The price of butcher's meat, in proportion to that of bread, is lower in England than formerly. The profits of all other kinds of productions are regulated by those of corn and pasture, except where the demand is much greater than the supplies; as in some vineyards, and the sugar plantations. Rice, yielding a greater quantity of food from the same land, than corn with the same labour, the rents from rice lands must be higher, provided there be a constant demand: the case is the same with respect to potatoes.

Human food is the only produce which necessarily affords rent. Materials for clothing and lodging in an uncultivated state of land are produced in great plenty: in an improved state there is generally such a demand as to afford rent. The most barbarous people exchange their superfluous materials of clothing with traders coming to their coast. The materials of lodging, stone, and timber, are not so easily conveyed, and therefore often remain unsold; in which case, they yield no rent, and only repay the labour of those who use them. Demand creates rent; as in the woods of Norway, and the stone quarries on the coast

of Scotland. In a rude state of society, clothing and lodging employ little labour: but, in the advancement of cultivation and division of labour, the labour of one family being able to provide food for two, or half the society for the whole, the other half will be employed in providing supplies for other wants or fancies of men. The desire of food is limited, that of other articles unbounded. Those therefore who can command more food, or more of what purchases it than is sufficient for themselves, lay out the surplus in procuring other articles, with which those who want food will be ready to supply them. Thus all the other products of land and labour arise from the improvements of the powers of labour in producing food. Coal mines afford rent sometimes: in some the produce is barely sufficient to pay the labour and profit of stock; others cannot be wrought on account of their unfavourable situation for demand. Wood rises in price as a country is cultivated; sometimes to such a degree, that notwithstanding the slow returns it makes, planting may become as profitable as cultivation. The value of metallic mines, particularly of the more precious metals, does not much depend upon situation, because they will bear the expence of carriage. Hence the price of metals at one mine may regulate that of others at a great distance. The mines of Peru yield no rent, except the tax of one-fifth to the King of Spain.

In consequence of the general progress of civilization the demand for silver (for use, ornament, and coin) will continually increase; if at the same time the supply does not increase in the same degree, the value of silver will gradually rise in proportion to that of corn: any given quantity of silver would exchange for a greater and a greater quantity of corn; or the money price of corn would decrease. Before the middle of the fourteenth century, the average price of the quarter of wheat was about four ounces of silver; from that time it fell gradually to two ounces of silver, at which it continued till about 1570. The price of corn sunk in the same manner in France, and probably in other parts of Europe; and, consequently, the value of silver increased. From mistaking the rent-price, or what we paid to the landlord in kind, for the market price—from inaccurate and defective registers, and from the very low price of wheat at some periods in ancient times, compared with other later periods—it has been inferred that silver decreased in value at the time under consideration: but, if the great increase of demand for silver be considered, and the best records of those times be consulted, it will appear, that whatever increase there might be in the quantity of silver it did not diminish its value. But if the supply by any accident increases in a greater proportion than the demand, silver would gradually become cheaper, or the average price of corn dearer. This was the case from about the year 1570 to 1640; doubtless owing to the discovery of the mines in America. During this period the price of corn rose from two ounces to between six and eight ounces of silver the quarter. If the supply of silver increases nearly in the same proportion as the demand, the average money-price of corn will continue nearly the same, or silver, notwithstanding all improvements or advances in real wealth, will not sink in value. The value of silver, in proportion to that of corn, seems never to have sunk lower than about the year 1636: in the present century it appears to have risen somewhat, notwithstanding the operation of the bounty on exportation. The prices at Windsor market to the year 1764 prove this: and the ad-

vanced price during the ten or twelve past years seems evidently to have been the effect of extraordinary unfavourableness in the seasons, and of the disorders in Poland. The increase in the price of labour is to be imputed to an increase in the demand for labour, not to a decrease in the value of silver. The gradual increase of the demand for silver in Europe, America, and the East Indies, has kept up its value. The proportion of the value of silver to gold is about 1 to 15. These valuable metals increase in a rich country because they are dearer, or a better real price is given for them. Though most commodities, except corn, come to exchange for a greater quantity of silver, it does not follow that silver is really cheaper, or will purchase less labour, but that these commodities are dearer, or will purchase more labour than before: their real as well as nominal price is raised.

The different sorts of rude produce may be divided into three classes—those which cannot receive much increase from human industry, as some birds, fishes, and other rare productions of nature, which being perishable cannot be accumulated—those which may be multiplied in proportion to the demand, as cattle and poultry—and those in which the efficacy of industry is either limited or uncertain, as wool, hides, fish, and precious metals. In the progress of improvement, the first may rise to any extravagance of price; the second has a limitation in the value of the ground employed to produce them; the third may be exceedingly variable in a state of continued improvement.

From the high or low money-price of commodities in general, nothing can be inferred, but that the mines are fertile or barren. But when cattle, poultry, and other produce are much cheaper than corn, the low state of agriculture and civilization may be concluded with great probability. The occasional rise of prices in some articles of provision will not prove a decrease in the value of silver, while the price of corn is not raised; for such partial advances may proceed from incidental causes, or be the effect of that increase of demand which increasing wealth naturally occasions. From what has been already offered it seems clear, that the value of money is not in reality diminished: we may therefore consider the advanced price of some articles of provision as a proof of the prosperity and wealth of our country.

Before division of labour is introduced into society, the accumulation of stock is unnecessary. After this, the greater part of a man's wants are supplied from the produce of the labour of others, purchased with the prices of his own. But this purchase cannot be made till the produce of his own labour is completed and sold. A stock of goods of different kinds, therefore, must be stored up somewhere, sufficient to maintain him, and to supply him with the materials and tools of his work, at least, till these events are brought about. And labour can be more and more subdivided only in proportion as stock is previously accumulated, because such subdivision implies an increase of materials and machines. On the contrary, accumulation of stock naturally leads to improvement, by giving the owner an opportunity of increasing the materials, and facilitating the operations of labour.

When a man possesses no more stock than would maintain him for a few days or weeks, he seldom thinks of deriving any revenue from it; but as it enlarges, he seeks a revenue from that part which is not necessary for immediate consumption. The part from which advantage is sought is his capital. Capital may be employed in raising, manu-

facturing, purchasing, and selling goods; or in the improvement of lands, purchasing tools, instruments, &c. The former is profitable only by circulation; the latter without it: the first may be called the circulating capital; the last, the fixed capital. Different occupations require different proportions between the fixed and circulating capitals employed in them. The general stock of any country or society is the same with that of all its members, and therefore is naturally divided into the same three portions. The first, for immediate consumption, includes the stock of food, furniture, clothes, houses, &c. The fixed capital consists of useful machines and instruments; profitable buildings, as shops, granaries, &c. improvements of land; and acquired useful abilities. The circulating capital is composed of money; stock of provisions for sale; materials of clothes furniture, and building, in the hands of the vender or manufacturer, or work finished but not disposed of. The fixed capital is derived from and supported by the circulating capital. The end of both is to maintain and augment the stock for immediate consumption, which constitute the riches of a people. This latter stock, as well as that which is fixed, is supplied from the circulating capital: and the circulating capital is supplied chiefly from three sources, the produce of lands, mines, and fisheries. These replace the capitals employed in them, and in all other concerns. All stock is employed in one of the three ways mentioned, except where money is hoarded, or effects concealed.

The whole price of the annual produce of any country must resolve itself into wages, profit, or rent. The real wealth of a country is its neat revenue, arising from the value of its produce, after deducting the expences of maintaining the fixed and circulating capitals, or what, without encroaching upon these capitals, they can devote to the consumption-stock. The intention of the fixed capital is to increase the productive powers of labour; the whole expence of maintaining it is to be deducted from the revenue; but in the circulating capital, the maintenance of the three parts, provision, materials, and finished work, does not diminish the neat revenue farther than is necessary for maintaining the fixed capital, because all besides this goes into the revenue. Money, then, is the only part of the circulating capital of a society, the maintenance of which can occasion any material diminution in the neat revenue. Money requires a considerable expence of materials and labour, first to collect and afterwards to support it; and in itself makes no part of the neat revenue of the society: it is the wheel of circulation, but altogether distinct from the goods which it circulates. A man's revenue consists not both in his money and the goods it will purchase, but more properly in the quantity of goods which he is able to purchase than in the money which he possesses. A guinea may be considered as a bill for a certain quantity of necessaries or conveniences, upon any of the tradesmen in the neighbourhood: the portion of wealth arising from hence consists not in the bill but the valuable commodities it will command. In like manner the revenue of a country is not both its money and consumeable goods, but only one of these; and the latter more properly than the former. Money, though a valuable part of the capital, is no part of the stock of a society.

Every saving in the expence of collecting and supporting that part of the capital which consists in money is an improvement of the revenue. Hence the utility of paper circulation, which supplies the place

of an expensive instrument of commerce with one less costly, and often more convenient. The credit of a banker gives his notes all the value of money in circulation. And twenty thousand pounds in cash being generally sufficient to answer all the occasional demands which may arise from a paper circulation of a hundred thousand, by this operation twenty thousand pounds perform all the functions of a hundred thousand; and the whole circulation will be carried on with one fifth of the specie necessary without it. When the quantity of currency is by this means increased beyond what is wanted in domestic transactions, a part of the money will be employed abroad in exchange for foreign goods, either to supply the consumption of some other country or their own. If for the former purpose, the profit will be an addition to the neat revenue of the country: if for the latter, it increases expence and consumption without increasing production, where it is employed in purchasing goods likely to be consumed by idle people, and is therefore hurtful; but where it is employed in increasing the fund of materials or provision for labourers, it promotes industry and wealth. This latter use of the overplus of currency is the most prevalent. It is therefore of advantage to society to increase the quantity of currency by paper, as it gives an opportunity of increasing the quantity of materials, tools, and maintenance for labour, and consequently of the produce of labour. This has been the effect in Scotland of the establishment of many private banks: business at home has been carried on by paper, and the coin has been chiefly employed in purchasing goods abroad. The paper currency in any country must not exceed the value of the gold and silver which would be necessary without paper for transacting the home business; for then the part not wanted would be brought for payment, which would occasion a run upon the banks, and oblige them to keep a larger sum of money always in hand to answer this increase of demand. This was the case some years ago in the Bank of England, and lately in the Scotch banks. When a sufficient sum cannot be commanded, recourse must be had to the ruinous expedient of paying backwards and forwards from one bank to another by notes, paying discount and all expences from the stock of the bank.

The judicious operations of banking, by substituting paper in the room of a great part of that gold and silver which was dead stock, and hereby enabling the country to convert this part into active and productive stock, are exceedingly beneficial in extending commerce; but paper currency must always be attended with more hazard than money, from the unskilfulness or knavery of bankers, or from general causes affecting public or private credit. Paper circulation for very small sums should be prohibited, in order to confine it as much as possible among traders, and prevent it from passing between traders and consumers, which would banish gold and silver almost entirely from the country. It is also necessary that circulating notes should be subjected to the obligation of unconditional payment; since any conditional clause must diminish their value.

Labour is productive or unproductive; productive, that which adds to the value of the subject on which it is bestowed; unproductive, that which has not this effect. The labours of manufacturers are of the former kind; those of persons employed in government, in liberal professions, in public diversions, menial servants, and many others, are

of the latter kind. Both these kinds of labourers, and those who do not labour at all, are maintained by the annual produce of labour and land. The greater portion of this produce is expended on the unproductive labourers, the less remains for the productive, and consequently the less will be the nett annual produce. All produce is employed either in replacing a capital or constituting a revenue; the capital immediately maintains none but productive hands; the revenue is the only source of support to unproductive labourers. Hence the proportion of these different classes of labourers depends greatly upon the proportion of the annual produce destined to replace a capital or constitute a revenue: and this proportion is different in rich and in poor countries; the share allotted to capital being much greater in the former than the latter. The proportion between these different funds, capital and revenue, determine the general character of the inhabitants of a country as to industry or idleness. We are more industrious than our forefathers, because our capital, destined for the encouragement of industry, is greater. Every increase or diminution of capital, therefore, naturally tends to increase or diminish the real quantity of industry, the number of productive hands, and consequently the exchangeable value of produce. Capitals are increased by parsimony, and diminished by prodigality and misconduct; for whatever is saved from the revenue is added to the capital, either to be employed by the person himself or others in labour. The prodigal, by encroaching upon his capital, diminishes the funds of industry, the quantity of labour, and the value of produce. Had the money wasted on unproductive hands been employed on labourers, there would have been an equal value of consumeable goods reproduced. And because the sole use of money is to circulate consumeable goods, money will increase or decrease in proportion to the quantity of these produced, that is to the quantity of capital employed in labour. Though private and public extravagance and misconduct tend to impoverish a nation, this tendency is counteracted by the uniform endeavours of individuals to better their condition. An increase of capital is necessary either to increase the number of productive labourers, or improve the instruments of labour: where this improvement or increase has taken place, a country has certainly enlarged its capital. England, notwithstanding all the perversion of annual produce from maintaining productive to maintaining unproductive hands, by private extravagance, public profusion, and expensive wars, has been continually increasing its capital. Some modes of private expence contribute more to the growth of public opulence than others. A man of fortune who spends his revenue in supporting a sumptuous table and retinue, lays up no stock by his mode of expence; but he who lives more frugally in these respects, and is expensive chiefly in furniture, clothes, books, pictures, and works of taste and elegance, gradually accumulates a stock, which may be considered as an addition to the public wealth; and, withal, gives employment to many labouring hands.

Stock lent at interest is always considered as a capital by the leader, and is generally employed as such by the borrower. All loans at interest, though made in money or paper, are in reality a transfer of a certain portion of the annual produce of the land and labour of the country, to be employed as the borrower pleases. The same pieces of money may serve successively as the instruments of different loans or

of repayment; it is not therefore the money which is borrowed, so properly as the power of commanding produce to the amount of that money. And the interest, in like manner, is the payment of a small portion of the annual produce to the lender. As general stock increases, the monied interest, or that stock which is to be employed upon interest, increases with it; and, from the natural operation of competition, the interest diminishes. The increase of the price of labour which will take place at this time, by diminishing the profits of the trader, will lower the interest of money. It is from these causes, and not from the increase of the quantity of money, that the general diminution of interest has taken place. Legal restrictions upon interest are necessary, to prevent the impositions of artful projectors; but the legal interest should always be fixed somewhat above the general market rate of interest.

Capital may be employed four different ways: in procuring rude produce; in manufacturing and preparing goods; in transporting produce or goods from one place to another; and in retailing them to consumers. Each of these methods of employing a capital is necessary either to the existence or extension of the other three, or to the general convenience of society. Equal capitals employed in each of these ways will put into motion very different quantities of productive labour. The capital and profits of the retailer replace the capital of the merchant; those of the merchant replace the capital of the farmer and manufacturer, and employ many labouring hands: those of the manufacturer, besides the replacing the capitals of those from whom he purchases his materials, employ a still greater number of productive labourers: but no equal capital causes so much productive labour as that of the farmer. The capital employed in agriculture and retail trade must always reside within the society: that of the merchant seems to have no necessary residence anywhere: that of the manufacturer must be where the manufacture is carried on; but it is not necessary that this should be where the materials grow, or where the goods are consumed. Where a country has not capital sufficient for the three purposes of agriculture, manufacture, and merchandize, it is expedient, not prematurely to attempt all the three, but to apply to that which will yield the greatest quantity of productive labour, and consequently add the greatest value to the annual produce. Thus, the rapid progress of the American colonies in opulence has been principally owing to their attention to agriculture.—The operations of capital differ farther, according to the different sorts of wholesale trade in which it is employed. Wholesale trade is of three kinds; the home trade; the foreign trade of consumption; the carrying trade. The capital employed in the home trade, purchasing in one part of the country in order to sell in another the produce of the industry of that country, generally replaces by every such operation two distinct capitals that had been employed in the agriculture or manufactures of that country, by bringing back commodities in return for those which are sold. The capital employed in purchasing foreign goods for home consumption, either directly or indirectly, with the produce of labour at home, in like manner replaces two capitals: but only one of them is at home; and the returns are not so quick as those of the home trade; this kind of trade, therefore, gives less encouragement to industry than the former. The capital employed in carrying the goods of one foreign

country to another, has no concern in supporting the productive labour of the country; and does not always necessarily increase the numbers of sailors or shipping, as the same capital might have employed an equal or greater number in the home or foreign trade of consumption. Each of these kinds of trade are advantageous and necessary, in their connection with each other; even the carrying trade in a wealthy nation may be a proper employment of that capital which is not required to support the productive labour of the country; but as sources of productive labour and wealth, the home and foreign trade of consumption are to be preferred.

Commerce is chiefly carried on between the inhabitants of the town and those of the country; and consists in a mutually beneficial exchange of natural produce and manufactures. The cultivation and improvement of the country, which affords subsistence, must be prior to the increase of the town, which furnishes only the means of convenience and luxury. The subsistence of the town depends upon the surplus of the country, and therefore the town can only increase with the increase of this surplus. The town is a continual fair or market, to which the inhabitants of the country resort, in order to exchange their rude for manufactured produce. In the natural course of things, therefore, the progressive wealth of towns must be consequential, and in proportion to the improvement of the country: the greater part of the capital of every growing society will naturally be employed, first in agriculture, then in manufactures, and afterwards in foreign commerce. But this natural order hath often been entirely inverted.

During the confusions which took place after the destruction of the Roman empire, the chiefs and principal leaders possessed themselves of the greater part of the lands. The lands thus engrossed were continued in a few hands by the law of primogeniture and the introduction of entails. These were adopted as the most effectual means of securing independence and power. It seldom happens that a great proprietor is a great improver: the owners of territory were too busy in securing and defending, to think of cultivating them beyond what had been usual. The tenants of lands, being such at will, were still less attentive to improvement. They were the property and slaves of their lords, and therefore could have no motive to attempt any kind of advantageous cultivation. Nor was any material improvements to be expected from that species of farmers, known in France by the name of netayers, and in Scotland by that of steel-bow tenants, who equally divide the profits with the landlord; for a tax amounting to one-half of the profits would be an insuperable discouragement. But farmers who pay a certain rent, under lease for a term of years, may find it their interest to lay out part of their capital for the improvement of their farms. The laws and customs so favourable to the yeomanry in England, have perhaps contributed more to its present flourishing state, than all the regulations of commerce. The services due to the landlord and to the public, which were so oppressive formerly, have been almost entirely removed. While the farmer lay under the difficulties abovementioned, little improvement was to be expected. And the ancient policy of Europe added still farther discouragements to the cultivation of land, by general prohibitions of exportation, by the absurd laws against engrossers, regraters, and forestallers, and by the privileges of fairs and markets.

The inhabitants of towns, long after the fall of the Roman empire, seem to have been chiefly tradesmen and mechanics; people of servile, or nearly servile condition, who travelled with their goods from place to place, and were subject to different kinds of taxes. But they appear to have risen to independence much earlier than the occupiers of lands. Having been accustomed to pay a poll tax to their lords or sovereign, for exemption from other tax, and from hence called free traders, these poll-taxes came in time to be farmed, and even by the burghers themselves, that is, became a fixed rent from a town. At length both the payment and exemption were made perpetual; and, consequently, ceased to belong to individuals, except as burghers of a particular burgh; from whence they were called free burghers. Other important privileges soon followed these, particularly those of incorporation. The true ground of these privileges probably was, that princes found it their interest to increase the power of the people against their common enemies the barons, and to encourage them in their combinations against their oppressors. Hence the privileges granted to English burghs, the institution of magistrates and councils of cities in France, the free towns in Germany, and the Hanseatic league. The sovereign having emancipated the people from the power of the nobles, sometimes lost his own dominion over them, and they formed themselves into independent republics; as in Italy and Switzerland. In other instances, though they continued their allegiance, they became so far free as not to be liable to be taxed without their own consent; and sent deputies to the general assembly of the states. These circumstances gave the inhabitants of cities and towns great advantage over those of the country, and encouraged them to exert their industry for improving their condition. Those towns which were situated on the sea-coast, or the borders of navigable rivers, enjoying an opportunity of bringing in their supplies from distant countries, and distributing their manufactures to a great extent, would first become opulent. Manufactures for distant sale seem to have been introduced two different ways; first, by the efforts of particular merchants and undertakers to establish them in imitation of some foreign manufactures of the same kind; these are generally employed upon foreign materials: secondly, by the gradual improvement of skill and taste, from the coarser manufactures common to all countries. These latter improvements often take place in inland countries, where there is a surplus of provision which cannot easily be carried to any great distance, and which therefore encourages labourers to resort thither. Such manufactures are the offspring of agriculture, as is the case with Birmingham, Manchester, Leeds, &c.

The increase and riches of commercial and manufacturing towns contributed to the improvement of the country three ways; by affording a great and ready market for the rude produce of the country; by providing purchasers of lands among the wealthy citizens; and by establishing order and good government, liberty and security. The state of dependence, in which tenants and retainers were before the introduction of commerce, was such as gave their lords little less than an absolute power. Territorial jurisdictions did not take their origin from the feudal law, but were known in their full extent long before this law prevailed: they necessarily flowed from the state of property and manners at that time. The introduction of the feudal law may be regarded as an attempt to moderate the authority of the great allodial lords,

by establishing a regular subordination, accompanied with a long train of services and duties, from the king down to the smallest proprietor. But it was the silent and insensible operations of foreign commerce which effectually reduced the oppressive power of the great proprietors of lands, by furnishing them with articles which they might consume by themselves, without sharing them with their tenants or retainers, and which therefore they would be tempted to purchase, even at the expence of that territory from which they derived their power. While they spent their rents in maintaining their tenants and retainers, they had this whole train in a state of dependence upon them: but by spending them upon manufacturers and artists they created no such dependence; for these having many employers could generally be maintained without the help of any single individual. Their expences being now turned into a new channel, a great part of their retainers were dismissed; the number of their tenants reduced, the rents of farms raised, and, the better to enable the farmer to bear such advances, long leases granted. This last circumstance greatly contributed to the independence of the farmer. In this manner great proprietors of land lost their power, and became as insignificant as any substantial burgher or tradesman. Commerce, by increasing the means of luxurious expence, has had a tendency to lessen the number of old family estates, and has occasioned, in the manner above described, the improvement of the country. The natural effect of commerce in multiplying small proprietors of land has been retarded by the laws of primogeniture and entail. In England, the progress of cultivation has followed slowly after the progress of commerce and manufactures, notwithstanding the encouragement which has been given to agriculture. Cultivation is in a lower state in France than England, though it had foreign commerce in a considerable degree near a century sooner than England. Spain and Portugal are in a still lower state of cultivation. Italy is the only great country in Europe, which seems to be universally cultivated and improved by means of commerce and manufactures. Its advantageous situation, and the great number of its independent states, have produced these effects. The capital acquired by commerce is a precarious possession, and can scarcely be said to belong to a country, till it has been secured and realized in the cultivation of lands. Great mercantile wealth has often been transferred from one country to another. The ordinary revolutions of war and government easily dry up the sources of that wealth which arises from commerce only. That which arises from the more solid improvements of agriculture is much more durable, and can only be destroyed by such violent convulsions as happened at the fall of the Roman empire.

The objects of political economy are, to provide the people with the means of plentiful subsistence, and to supply the state with a revenue sufficient for the public services. For the purpose of enriching the people, two different systems have been adopted, the one the system of commerce, the other that of agriculture. Let us examine each of these distinctly.

It has long been a popular error, that wealth consists in money, or gold and silver. This idea formerly gave rise to frequent prohibitions of the exportations of money or bullion. These were opposed by merchants as ineffectual, unnecessary, and injurious to the balance of trade. But still the opinion that the national wealth con-

sisted in money, was retained; the attention of government was directed to the preservation of a favourable balance of foreign trade, as the true means of increasing the national treasure: and home trade was not considered as a source of wealth, except as it was subsidiary to foreign trade. But there is in reality no necessity that, in either of these ways, the attention of government should be employed on the increase of money. The quantity of money, like that of every other commodity, will always be regulated by the effectual demand. Where a greater quantity is imported than exceeds this demand, no vigilance of government can prevent its exportation; when the demand is greater than the present supply, no prohibitions will prevent its importation. Money is only scarce where individuals have not wherewithal to purchase it, nor credit to borrow it, which will generally happen where great profits occasion over-trading. But a country which abounds with the produce of land or labour, beyond what is necessary to supply the home consumption, has always the power of commanding an increase of its treasure, by sending its surplus to foreign markets. The greater part of this surplus, however, is always destined to the purchase of foreign goods: and while a country is able to procure these, its trade may be beneficial without any increase of money: its annual produce of land and labour and its real gains being nearly the same. Since money is merely a convenient instrument of circulation, no benefit can be derived from increasing it farther than it is wanted for this purpose. It is not always necessary to accumulate gold and silver, in order to enable a country to carry on foreign wars. These may be supported either by sending abroad some of its gold and silver, or some of the produce of its manufactures, or some of its annual rude produce. The late wars in Europe have had little dependence on the exportation of money or bullion, but have been chiefly carried on by the exportation of manufactures: the government contracting with merchants to make the necessary remittances, who would do it either directly or indirectly by sending over goods, which would bring him a profit. A country which produces a great surplus of the finer manufactures may carry on an expensive foreign war without exporting any considerable quantity of gold or silver, and may enrich its merchants while it is exhausting its own strength. Rude produce alone would not be adequate to the purpose; the expence of exportation would be too great. The chief benefit of foreign commerce is, not the importation of gold and silver, but the exchanging of superfluous produce of land and labour, for those articles of foreign produce which are wanted at home. It is on this account that the American connexions have proved so beneficial to Europe; and those of the East would have been no less so, had not the natural operations of commerce been obstructed by exclusive companies. The continual exportation of silver, so much complained of, produces no material effect. The East India trade, by opening a market to the commodities of Europe, or, which comes nearly to the same thing, to the gold and silver which is purchased with these commodities, tends to increase the annual production of European commodities, and consequently the real wealth and revenue of Europe.—The false principles, that wealth consists in gold and silver, and that these could only be commanded by the balance of trade, have rendered it a great object in political economy to lay restraints upon importation, and to give encouragement to exportation.

The restraints upon importation have been upon such foreign goods as could be produced at home—and upon goods of almost all kinds from those countries with which the balance of trade was supposed to be disadvantageous.

By the first of these restraints, the monopoly of the home market is more or less secured to domestic industry. But whether it tends to increase the general industry, or to give it the best direction, may be questioned. It cannot increase the industry of the society beyond what its capital can employ; it can only give it an artificial direction. Now, without this, every individual will endeavour to employ his capital as near home as he can, and consequently as much as he can in support of domestic industry, provided he can nearly obtain the ordinary profits of stock; and will therefore employ it most advantageously to his country, by directing it into that channel which will give revenue and employment to the greatest number of people of his own country. And every individual who employs his capital in the support of domestic industry, naturally endeavours to direct it in the most profitable manner. Every individual, therefore, necessarily labours to render the annual revenue of the society as great as he can, without immediately intending it. What species of domestic industry will be most profitable, each individual is the best judge for himself. But the statesman, by giving the monopoly of domestic industry in any particular art or manufacture, in some measure takes upon him to direct in what manner private people ought to employ their capitals: and the regulation will generally be either useless or hurtful. It is for the benefit of the public, as well as individuals, to purchase from others such articles as can be bought cheaper than they can be made at home: for that labour which would be employed in making them may be directed into a channel which will be more advantageous, that is, make a more valuable addition to the annual produce. Whatever aid such regulations may give to particular manufactures, they therefore naturally tend to diminish the general revenue. The chief benefit of the monopoly of the home market is enjoyed by merchants and manufacturers: the prohibition of the importation of foreign cattle and salt provisions, and high duties upon foreign corn, are not so beneficial to the graziers and farmers of Great Britain, as other regulations of the same kind are to its merchants and manufacturers, on account of the great expence of carrying the more bulky commodities. The free importation of foreign corn could very little affect the interest of the farmers of Great Britain. The average quantity imported annually amounts only to 23,728 quarters, which is not a five hundredth part of the annual consumption. There are two cases in which it may be advantageous to lay some burdens upon foreign, for the encouragement of domestic industry. The first is when some particular sort of industry is necessary for the defence of the country: hence the propriety of the navigation act, which gives the sailors and shipping of Great Britain a monopoly. The second case is, when some tax is imposed at home upon the produce of domestic industry: here an equal tax upon the like foreign articles is necessary to leave the competition between foreign and domestic industry upon the same footing as before. When a foreign country restrains by high duties or prohibitions the importation of any of our produce or manufactures, it becomes a matter of deliberation whether the free importation of their goods is to be continued: there seems to be good policy in this

kind of retaliation, only when there is a probability that it will procure the repeal of the high duties or prohibitions complained of: otherwise we only punish ourselves by making certain goods dearer than before. When particular manufactures, by means of high duties or prohibitions on all foreign goods that come in competition with them, are greatly extended, and employ a multitude of hands, it may be questioned how far, or in what manner, free importation should be restored. This might, however, be done gradually with less inconvenience than is commonly supposed: manufactures exported without a bounty, being sold as cheap abroad, and therefore cheaper at home than foreign goods of the same kind, would be very little affected by free importation: and those who might be thrown out of employment in any particular manufacture would easily direct their industry into some other channel, at least as easily as disbanded soldiers turn themselves to different kinds of labour. But the interests of many individuals so strongly oppose free importation, that it would be extremely hazardous to attempt to introduce it, except by very slow degrees, and after a very long warning.

The restraints which are laid upon the importation of goods of almost all kinds, from countries with which the balance of trade is supposed to be unfavourable, are unreasonable even upon the principles of the commercial system. For, though the balance might, by a free trade, be rendered more unfavourable with respect to one country, if the goods purchased from that country were cheaper than could be procured from other countries, the general balance of the whole trade would become more favourable by such free importation. Besides, a great part of them might be re-exported, and sold with profit. To which must be added, that there is no certain criterion by which the balance of trade between any two countries can be determined. In custom-house books, entries are defective, and valuation inaccurate. The course of exchange is a rule of judging almost as uncertain. Exchange is said to be at par between two countries, when for a sum of money containing a certain number of ounces of pure silver in the coin of one country, a bill is given to receive a sum containing an equal number of ounces of pure silver in the coin of the other: when you pay more you give a premium, when less you get a premium, and the exchange is in favour or against your country. The payment of a premium is said to be a sign that the balance is against a country, because it supposed that money or bullion is to be sent over to pay the balance, for the hazard and expence of sending which the premium is charged. But it must be considered, that we cannot always judge of the value of the current money by the standard of their respective mints; that the expence of coinage being defrayed by government in some countries, and by private persons in others, may make a difference in the value; and that in some places foreign bills of exchange are paid in the current coin, in others in bank-money which is always of more value than the currency; from all which circumstances, uncertainty must arise concerning the real state of exchange.

In small states, where the currency is usually made up of the coins of several countries, in order to remedy the inconvenience which would arise from the uncertainty of the current coin, it has been agreed to pay bills of exchange from the bank in good money of the state. The banks of Venice, Genoa, Amsterdam, &c. seem to have been established for

this purpose. The money of the bank being better than the currency, bears an agio, or a difference in value in favour of the bank. This money also is more secure from accidents, and may be paid by a simple transfer without trouble or risk. The bank of Amsterdam receives gold and silver bullion at certain prices. It sells at all times bank money for currency at five per cent. agio and buys at four. For every guilder circulated as bank money, the city is guarantee that a correspondent guilder shall at all times be found in the treasure of the bank.

From the nature of these banks, and other circumstances, the exchange between countries that pay in bank money, and those which pay in currency, must generally appear to be in favour of the former. But if the ordinary course of exchange gave an accurate idea of the state of debt and credit between two countries, this is usually so much affected by the connections of each with other countries, that nothing certain can be deduced from hence.

Prohibitions of importation then appear to be unreasonable on the principle of the importance of preserving a balance of trade. But nothing can be more absurd than this whole doctrine. A trade carried on naturally and regularly between two countries is always advantageous, though not equally so, to both; for it increases the exchangeable value of the annual produce of land and labour, that is, the revenue of both. If the balance be even, and the trade consist altogether in the exchange of native commodities, both will be gainers, and nearly equally, for each country affording a market for the overplus of the other, each will replace the capital which had been employed in raising this surplus, and had given revenue and maintenance to a certain number of its inhabitants. If the balance be even, and the trade on one side with foreign goods, and the other with native commodities, the latter would gain more than the former, because the revenue arising from the trade will be divided between two countries in one case, and remain in one country in the other. But whether the balance of trade be favourable to one country, or to another, the trade itself is beneficial to both. It is the interest of merchants and manufactures to secure the monopoly of the home market: but it is undoubtedly the interest of the country to purchase goods of those who sell them cheapest, whether natives or foreigners. A rich nation may be a more formidable enemy, but will certainly be a better customer to a commercial nation, than a poor one. Nothing, therefore, can be more absurd than to aim at impoverishing our neighbours in order to enrich ourselves. On the whole, the prosperity or decay of a nation does not depend upon the balance of trade, which may be against it while it is increasing in real wealth, but upon the balance of produce and consumption. The society in which the exchangeable value of its annual produce exceeds that of its annual consumption is increasing its revenue, and is therefore in a prosperous state, whatever may happen with respect to its coin.

The means employed for encouraging exportation have been drawbacks, bounties, treaties of commerce, and colonization.

Drawbacks, by which the merchant is allowed to draw back, upon exportation, either the whole or a part of the duties imposed upon domestic industry, serving not to overturn the balance which naturally takes place among the several employments of society, but to hinder it from being overturned by the duty, are justifiable and useful. The

same may be said of the drawbacks upon the re-exportation of foreign goods imported.

Bounties are only reasonable in those branches of trade which cannot be carrried on without them. Their effect is, to force the trade of the country into a channel much less advantageous than that in which it would run of its own accord. The bounty upon the exportation of corn renders it somewhat dearer in the home market than it would otherwise be, and somewhat cheaper in the foreign: the effect of which is, that, as the average money price of corn regulates more or less that of all other commodities, it lowers the value of silver at home, and raises it a little abroad: hence it renders our manufactures somewhat dearer, and discourages them, without rendering any real service to the farmer, who has only a nominal benefit. Bounties on such articles of production and importation as are necessary for defence, may be expedient. All the restrictions of law to prevent or limit engrossing and forestalling, to reduce the price of corn by fixing its utmost extent, to annihilate or confine the trade of the corn-merchant or dealer, to prohibit or discourage either the importation or exportation of corn, or to prevent the trade of the merchant carrier of corn from one country to another, proceed upon false principles, and are injurious to the interests of the country.

Treaties of commerce in favour of any particular country, giving it commercial privileges superior to other countries, though beneficial to the merchants and manufactures of the privileged country, are necessarily disadvantageous to the country which grants the favour, because a monopoly is established against themselves, which must generally raise the price of goods higher than where a free competition is permitted. Such a monopoly has sometimes been granted from an expectation that it would produce a balance of trade in favour of the country granting it, by encouraging the sale of its manufactures in the country thus distinguished. This is the foundation of the treaty of 1703 between England and Portugal; which binds Portugal to receive English woollens, but not on better terms than those of other nations, and obliges Great Britain to admit the wines of Portugal at two-thirds the duty of those of France, and is therefore disadvantageous to Great Britain. The importation of gold or silver from Portugal is of much less consequence than is commonly supposed; the greater part of it being re-exported in exchange for consumable goods, which might be purchased with greater advantage, by a direct trade, with the produce of English industry.

Colonies were established among the ancients from motives different from those which have directed their establishment in modern times. The colonies from the states of Greece were emigrations proceeding from the excess of population. Those of the Romans were grants to the people to silence their complaints of the unequal distribution of lands at home. The expectation of finding gold and silver mines, joined with that of discovering a north-west passage to the East Indies, occasioned the conquest and settlement of America.

The colony of a civilized nation, established in a waste country, or one in which the natives easily give way to the new settlers, advances rapidly to wealth and greatness. Their knowledge of agriculture, their habits of subordination, the great encouragement to industry which the easy purchase of land affords, and the extraordinary profits which will

arise from the produce, notwithstanding the high price of labour, are circumstances which concur to hasten the progress of improvement and wealth. The American settlements, besides these advantages, have had that of an easy dependence on the mother country. The political institutions of the Canadian colonies have been peculiarly favourable to the improvement and cultivation of land. Among them the engrossing of uncultivated land has been restrained; the right of primogeniture is not universal; the alienation of lands is easy; the taxes are moderate; and the market allowed for the sale of their overplus produce is more extensive than that of any other colonies. All the different civil establishments in North America, exclusive of Maryland and North-Carolina, of which no exact account has been given before the disturbances in 1776, did not cost the inhabitants above £64,700 a year. It is only with regard to certain commodities that the Canadian colonies are confined to the market of their mother country. These are called enumerated commodities. Among the non-enumerated are included the important articles of grain, lumber, salt provisions, fish, sugar and rum. The enumerated goods are chiefly, molasses, coffee, cocoa-nuts, tobacco, pimento, ginger, whale fins, raw silk, cotton wool, beaver, and other peltry of America, indigo, fustic, and other dying woods, naval stores, pig and bar iron, copper ore, pot and pearl ashes. In every thing, except their foreign trade, the liberty of the Canadian colonists to manage their own affairs their own way is complete. From the nature of their assemblies and government, there is more equality among them than among the inhabitants of the mother country. It must, however, be acknowledged, concerning the British, as well as other colonies, that the mother country has had little merit either in projecting or effectuating their establishment, and that the monopoly in trade has tended to retard the progress of the colonies, and has been only somewhat less illiberal and oppressive than that of other European nations over their colonies.

The general advantages which Europe has derived from the discovery and colonization of America, consist in the increase of its enjoyments, and the augmentation of its industry. Both these effects are much restricted by the exclusive trade of the mother countries. Each colonizing country derives peculiar advantages from its colonies by means of its exclusive trade, increasing both its enjoyments and industry: but these advantages are only relative with respect to other nations; and to obtain them, both absolute and relative disadvantages are incurred in almost every other branch of trade. The English monopoly hath been continually drawing capital from all other trades to be employed in that of the colonies, and consequently hath injured other branches of trade to encourage this: it hath also kept up the rate of profit in all the different branches of trade, higher than it would naturally have been. By lessening the competition, it increased the profits in the colony trade; and by lessening the competition in other branches, it raised the profits of these likewise. Now an advance of profit requires an advance of price, which is unfavourable to trade, and enables other countries, to undersell that which labours under this disadvantage. The monopoly of the colony trade has also been injurious, by forcing the foreign trade from neighbouring countries, from which returns being frequent, a greater quantity of labour may be employed, to countries more remote, which not admitting of frequent returns, must in this view be less ad-

vantageous; and by forcing some part of the capital of Great Britain from a direct foreign trade of consumption to a round-about one: this must be the case with respect to such enumerated goods as are imported in greater quantities than are necessary for home consumption. Another inconvenience arising from the monopoly is, that it has turned the stream of British industry too much into one channel, and destroyed the natural balance which would otherwise have taken place among its different branches. The natural effects of the colony trade are, however, so beneficial, that they have greatly overbalanced all the bad effects of the monopoly.—By raising the rate of mercantile profit, the monopoly discourages the improvement of land; and encourages superfluous expence among the merchants.

Notwithstanding the great and obvious disadvantages of this monopoly, the maintenance of it has been the principal end of the dominion which Great Britain assumes over her colonies. The whole expence of defending and preserving the colonies is therefore in reality a bounty to secure a pernicious monopoly. A peaceable separation would establish a free commercial intercourse, more beneficial than the monopoly. In order to render the provinces, in a state of dependence, advantageous to the empire, it ought to support its own peace establishment, and contribute its proportion to the general expences of government. It is not probable that this should be obtained from the colony assemblies. It has therefore been proposed, that the colonies should be taxed by requisition; the sum to be specified by the British parliament, and the provincial assemblies to be at liberty to raise it in their own way. If this contribution were to be regulated by the land-tax, parliament could not tax the colonies without taxing its own constituents, and they might be considered as virtually represented. The members of the congress and their dependents are elevated to such a degree of consequence, that no method seems more likely to engage them to a voluntary submission, than giving the leading men of each colony an opportunity of continuing and increasing their consequence, by allowing each colony which should detach itself from the general confederacy, a number of representatives in the British parliament proportioned to its contribution to the public revenue.

The establishment of exclusive companies is another species of pernicious monopoly. In poor countries this monopoly attracts towards the trade thus limited more stock than would otherwise go to it: in rich countries it prevents the employment of so much stock in it as might otherwise be expected: in both it is injurious. Nor are such companies necessary: for when a nation is sufficiently rich, some merchants would naturally turn their capital towards the different branches of the trade thus monopolized, as soon as it should be laid open.

Having thus considered at large the system of commerce, we are now briefly to take notice of that of agriculture.

Mr. Colbert, the famous minister of Louis XIV. adopted the mercantile system so far as to lay great discouragements upon agriculture. In opposition to his system, the French philosophers proposed one which represented agriculture as the only real source of wealth. The cultivators of ground, because their labours afford a neat produce to the landlord after paying completely all the necessary expences of cultivation, are called the productive class. Artificers, manufacturers, and merchants, replacing only the stock which employs them, together with

its ordinary profits, are said to be unproductive. These are maintained wholly at the expence of the proprietors and cultivators of lands: but it is their interest to encourage them, because it enables them to purchase the produce of labour much more advantageously than they could otherwise have done, and thus raises the value of the surplus produce of the land. The capital error of this system, of which Mr. Quesnai was the author, consisted in representing the class of manufacturers and merchants as unproductive; for this class reproduces annually the value of its own annual consumption, and its labour fixes and realises itself in some vendible commodity: to which may be added, that manufactures and merchandize increase the stock of provision by enabling one country to procure a greater quantity from another. The political economy of many nations has been more favourable to agriculture than commerce. This is the case in China, as it was formerly in Egypt and in Indostan. The sovereigns of these countries have derived their principal revenue from some sort of land tax. Among the ancient Greeks and Romans, trade and commerce were discouraged. All discouragements of trade are unfriendly to agriculture; because the dearer manufactured produce is, that is, the less quantity of it can be purchased by a certain quantity of the produce of land, the cheaper or less valuable is this latter produce.—On the whole it appears, that all the extraordinary encouragements, or restraints, proposed either in the commercial or agricultural system, are detrimental, and retard the progress of society towards wealth and greatness; and that the obvious and simple system of natural liberty, in which every man is left to employ his capital or industry as he pleases, is most agreeable to the true principles of political economy.

The expences of government are of four kinds, those of defence—of justice—of public works and institutions—and for supporting the dignity of the sovereign.

The expences of defence are very different in different states of society. Among nations of hunters and of shepherds every man is a warrior. An army of hunters can seldom exceed two or three hundred men: an army of shepherds may sometimes amount to two or three hundred thousand: a nation of the latter therefore is more formidable than one of the former. In a nation of husbandmen, where there is few manufactures and little commerce, every man easily becomes a warrior, and the expence of collecting an army is small. In this state of society, the men who were of age to bear arms have often served without pay. But in a more advanced state, this became impossible. Artificers and manufacturers, having no revenue but in their daily labour, must be maintained by the public while they bear arms in its defence. This is become still more necessary, since the art of war has been refined into an intricate science, and the event has remained undecided for several campaigns. The expences of war have been greatly increased from the time that the military character became distinct and separate, and the preparation and maintenance of armies devolved upon government. As society refines, and manufactures increase, voluntary military exercises are neglected, and it becomes the business of the government to provide for the security of the people. This may be done, either by enforcing the practice of military exercises on the whole or part of the people capable of bearing arms, or by maintaining and employing a certain number of citizens in the constant practice of military exercises:

the former creates a militia, the latter a standing army. A militia must always be much inferior, both in dexterity and in ready obedience, to an army composed of men who are soldiers by profession. Ancient history confirms this remark. It is only by a standing army that the civilization of any country can be perpetuated. A standing army can only be dangerous to liberty when the interest of the general and officers is not necessarily connected with the support of the constitution of the state. Where the military force and civil authority are united, the sovereign enjoys such security as renders it safe for him to tolerate that degree of liberty which approaches to licentiousness. The expences of war have been much increased by the introduction of fire-arms.

The establishment of an exact administration of justice, necessary to defend every member of the society from injustice or oppression, is attended with different degrees of expence in different periods of society. Where property is great and unequally distributed, frequent occasions of injury occur, and magistracy becomes necessary. Subordination naturally increases with the growth of valuable property. Fortune and birth are the two circumstances which principally set one man above another: these create dependence and respect, and thus naturally introduce judicial authority. The exercise of this authority for a long time, far from being a cause of expence, was a source of revenue. This was found to be productive of gross abuses, and when taxes came to be paid for the support of government, it seems to have been stipulated that no present should be accepted for the administration of justice. It is not to be expected, however, that justice should be administered gratis. To prevent the corruption of justice, the higher officers may be paid by government; but lawyers and attornies must be paid by the parties, or they would perform their duty still worse than at present. The whole expence of justice might easily be defrayed by the fees of court: and indeed these fees seem originally to have been the principal support of the courts of justice in England.

Another object of national expence is the erecting and maintaining public useful institutions and works, the profit of which could not repay the expence to private individuals. These are chiefly such as are designed for facilitating commerce, for the education of youth, and for the instruction of the people.

Public works for facilitating commerce, such as highways, bridges, harbours, canals, &c. will generally afford a particular revenue for defraying their own expence, in the hands of private persons or trustees. To remedy the evils complained of, arising from the mismanagement of public tolls or turnpikes, it has been proposed that the affair should be taken into the hands of government, and the soldiers be employed in mending the highways But in this case, these tolls, being considered as one of the resources of the state, would probably be greatly augmented; a very unequal burden would fall upon the lower classes of the people; and the remedy, on the supposition of neglect, would be more difficult.

Institutions for the education of youth may likewise furnish a revenue sufficient for defraying their own expence, arising from the fees of the scholars. The endowments of schools or colleges, by diminishing the necessity of application and exertion in the teachers, have in some measure frustrated the end of their institution. In the university of Oxford, the greater part of the public professors have, for these many years,

given up altogether even the pretence of teaching. Whatever forces a certain number of students to any college or university, independent of the merit of the teachers, tends to diminish the necessity of that merit. Of this kind are exclusive privileges of graduates, and charitable foundations. If the discipline of the college be contrived for the interest or ease of the masters rather than the benefit of the students, as is frequently the case in endowed institutions, the effect must be unfavourable to the interests of learning. The present universities of Europe were originally, for the most part, ecclesiastical corporations instituted for the education of churchmen. What was taught in them was, accordingly, theology, or some things preparatory to theology. A corrupt Latin, which was the common language of the western parts of Europe when Christianity was established by law, long continued to be used in the church; and therefore the study of it was made an essential part of university education. Greek was introduced in consequence of the disputes which arose between the Catholic and reformed churches. The ancient Greek philosophy, which had been judiciously divided into physics, or natural philosophy, ethics or moral philosophy, and logic, in order to accommodate it to theological students, was changed for a system consisting of these five parts, logic, ontology, metaphysics, moral philosophy, physics. In this course, so large a quantity of subtlety and sophistry, of casuistry and ascetic morality, were introduced, as rendered it very improper for the education of gentlemen or men of the world. This course, or a few unconnected shreds and parcels of this course, still continue to be taught in most of the universities of Europe. And the richest and best endowed universities have generally been the slowest in adopting improvements, and the most averse to alterations. Among the Greeks and Romans the state seems to have been at no pains in the business of education, except so far as related to military exercises; yet masters were found for instructing the better sort of people in every art or science which it was necessary or convenient for them to study. Were there no public institutions for education, teachers would never find their account in teaching either an exploded and antiquated system of a science acknowledged to be useful, or a science universally believed to be a mere useless and pedantic heap of sophistry and nonsense; and a gentleman, after going through a long and expensive course of education, could not come into the world completely ignorant of every thing which is the common subject of conversation among gentlemen and men of the world. Perhaps, in civilized and commercial society, the state may, with advantage, pay some attention to the education of the common people, who are always rendered more orderly and useful by well chosen instruction. By establishing parish schools for reading, writing, and accounts, and perhaps the elementary parts of geometry and mechanics, giving premiums to those who excel, and obliging every man to undergo an examination in the essential parts of education before he be allowed to set up any trade, or obtain the freedom of corporations, the public might, at a small expence, facilitate, encourage, and even impose upon the common people, a necessity of acquiring some education.

Institutions for the general instruction of the people in religion derive no advantage from independent endowments, respecting the zeal and industry of teachers. If they are more learned and accomplished than those who do not enjoy endowments, they have generally less influence

over the inferior ranks of the people; and have therefore always found it necessary to call for the support of the civil magistrate against their opponents. In civil disputes, that religious sect which has been leagued with the victorious party has generally been powerful enough to oblige the civil magistrate to respect their opinions and inclinations; and their clergy have required that he should silence and subdue their adversaries, and bestow an independent provision on themselves. Had politics never called in the aid of religion, it would have dealt equally and impartially with the different sects. This would have increased their number, but, by dividing their strength, it would have been productive of moderation and good temper. Religious sects, being generally begun among the common people, usually adopt an austere system of morals, sometimes indeed carried to an extravagant height, but on the whole favourable to good order. Where there is an established or governing religion, the sovereign cannot be secure unless he has the means of influencing the clergy: which is most successfully done by keeping their honours and preferments in his hands. Church preferment was very early at the disposal of the church. At length, the Pope gradually drew to himself the collation of bishoprics, abbacies, and inferior benefices; and thus the clergy through Europe were formed into a kind of spiritual army under one general; not only independent of the sovereigns of their respective countries, but dependent upon one foreign sovereign. Thus did the church of Rome, through the tenth, eleventh, twelfth, and thirteenth centuries, maintain the most formidable combination that ever was formed against the authority and security of civil government, as well as against the liberty, reason, and happiness of mankind. The gradual improvements of arts, manufactures, and commerce, destroyed at the same time the power of the great barons and of the clergy. By furnishing them with more opportunities of spending their riches upon themselves, and increasing their desire of gain, they led them to render their tenants independent upon them by granting them long leases, and put an end to that hospitality and charity which had given them such influence with the people. In this situation of things, the sovereigns endeavoured to recover their influence in the church, by procuring to the deans and chapters of each diocese the restoration of their ancient right of electing the bishop, and to the monks that of electing the abbot. This was the object of several statutes in England in the fourteenth century, and of the pragmatic sanction established in France in the fifteenth century. Other similar regulations took place in other parts of Europe; and the authority of the Pope gradually declined. The reformation greatly aided the efforts of the sovereigns of Europe against the power of Rome. Henry VIII. of England renounced the Pope's supremacy. The reformation gave birth to two principal parties, the Lutheran and Calvinistic; the former of whom preserved episcopal government and clerical subordination, and gave the sovereign the disposal of bishoprics and superior benefices: the latter gave the people the right of electing their ministers, and established a perfect equality among the clergy. To prevent the frequent disturbances which occurred, the magistrate resumed the right of presentation. Moderate benefices are most favourable to the usefulness and respectableness of the clergy.

The expences necessary to support the dignity of the sovereign must increase in an improving state of society.

The sources of the general or public revenue, from which the several expences of government may be defrayed, are the funds which belong to the sovereign or commonwealth, or taxes upon the people.

The sovereign may derive a revenue from the profit of stock employed in merchandise, as, by taking the public bank, post-office, &c. into his hands, or engaging in mercantile projects. But it has always been found that the character of the trader and sovereign are inconsistent. A state may derive part of its revenue from the interest of money, as is the case with the canton of Berne. The rent of public lands has been found a more secure and permanent source of revenue than either of the former; but these would be better improved and yield a greater revenue, by being in the hands of private persons. Since the modern art of war and other refinements have rendered government so expensive, public stock and lands have been found improper and insufficient sources of revenue, and taxes on the people have become necessary.

The subjects of every state ought to contribute to the support of government in proportion to the revenue which they enjoy under the protection of the state. The tax to be paid by each individual should be certain and not arbitrary. Every tax should be levied at the time and in the manner most convenient to the contributor. And every tax should be so contrived as to take and keep out of the pockets of the people as little as possible above what is brought into the public treasury. All private revenue arising from rent, profit, and wages, every tax must fall upon some one of these separately, or upon all of them indifferently.

Taxes upon the rent of land may either be according to some fixed canon, or variable, according to the variations in the real rent of the land. A land-tax on the former plan necessarily becomes unequal. In Great Britain the rents of lands have universally risen, and given all the proprietors of lands an advantage, though in very unequal degrees. A variable land-tax has its inconveniences; particularly, it would, without great precaution, discourage the improvement of lands. Taxes upon the produce of land are, in fact, taxes upon the rent. Tythes are a very unequal tax, and a great discouragement to cultivation. A tax of this sort, paid in kind, would be liable to suffer much from mismanagement. A certain sum of money, or modus, in lieu of such taxes, or tythes, would be more uniform, and would not discourage improvement. A tax upon the rent of houses would fall partly upon the tenant and partly upon the owner of the ground. The proportion of the expence of house rent to the whole expence of living, is highest in the first ranks of life, and gradually diminshes: a tax upon house rents would therefore generally fall heaviest upon the rich. A tax upon ground rents would fall altogether upon its owner; and would be easy and equitable, as these rents are in proportion to the populousness and wealth of any place. Window taxes are unequal, falling much heavier upon the poor than the rich.

Profit, or the revenue arising from stock, may be divided into the part which pays the interest, and the surplus. The latter is not taxable directly, for this being the natural compensation to the employer, such a tax would oblige him either to raise the rate of profit, or sink that of interest. The interest of money is not a proper object of taxation, because the amount of a man's capital stock is not easily known, and because it is liable to be removed, and might be driven away by a vexa-

tious tax. The tax upon stock in England, though annexed to the land-tax, is much lighter; it is rated much below its real value. Taxes upon particular branches of trade are taxes upon stock: as those upon pedlars, hackney-coaches, and ale-houses. A tax upon the profits of stock, in a particular branch of trade, lays a restraint upon the market: a tax upon the profits of stock in agriculture falls upon the landlord. All taxes upon the transference of property of every kind, so far as they diminish the capital value of that property, tend to diminish the funds destined for the maintenance of productive labour, and therefore are injudicious.

Taxes upon labour, where the demand for it, and the price of provisions remain the same, fall immediately upon the employer, and finally upon the landlord and the consumer. These are extremely injurious to the public, and oppressive to individuals. The emoluments of offices, being generally higher than is necessary, might properly be taxed.

The taxes which are intended to fall indifferently on every different species of revenue, are capitation taxes, and taxes upon consumable commodities.

Capitation taxes, if it is attempted to proportion them to the revenue of each contributor, become altogether arbitrary: if they are proportioned by rank, they become unequal. As far as they are levied upon the lower ranks of people they are direct taxes upon labour; they are always burdensome and unpopular.

Consumable commodities are either necessaries or luxuries. Necessaries are those things which nature and the established rules of decency have rendered necessary to the lowest class of the people. In England a linen shirt and leather shoes are become necessaries. A tax upon necessaries is a tax upon the wages of labour; because labourers must pay more for them. Taxes upon the luxuries of the poor act as sumptuary laws, disposing them to refrain from or moderate the use of superfluities. Taxes upon necessaries or labour fall doubly upon landlords, by reducing their rents and increasing their expences.

In Great Britain the principal taxes upon the necessaries of life are those upon salt, leather, soap, and candles. Coals, though a necessary article, are taxed very highly when carried coastwise, but pay no duty by land-carriage or inland navigation. Where they are naturally cheap, they are consumed duty free; where dear, loaded with a heavy duty. Consumable commodities may be taxed either by demanding an annual sum for using them from the consumer, or by levying a tax upon them while they are in the hands of the dealer: the first method suits such goods as last a considerable time, the latter those of which the consumption is more immediate.

The prohibition of, or high duties imposed upon, the importation of many foreign goods, has annihilated or diminished the revenue from them, without being of real benefit to trade. Perhaps the duties of customs might, without any loss to the revenue, and with much advantage to trade, be confined to a few articles only. The whole consumption of the inferior ranks of people being much greater in value as well as quantity, than that of the superior and middle ranks, those taxes which are laid upon the luxuries of the common people must be most productive. Hence the great benefit of the taxes on the materials and manufacture of fermented liquors. And this tax might be rendered

more equal, as well as profitable, by taking off the different duties upon beer and ale, and tripling the malt-tax.

In that rude state of society which precedes the extension of commerce, few articles of luxury are to be obtained, and those who possess a large revenue usually spend the surplus in hospitality and charity. In this state few persons live beyond their income, and many hoard up treasures; among the rest, the sovereign. In a commercial country, both the people and sovereign finding new sources of expence, live up to and often beyond their income. The want of parsimony in a state in times of peace, imposes the necessity of contracting debt in the time of war. In the immediate exigences of war, government can have no resource but in borrowing. The increase of wealth in a commercial country, and the security of property in a free state, introduce an ability and willingness in the subject to lend their money to government on extraordinary occasions.

Public debts are contracted on what may be called personal credit, without assigning or mortgaging any particular fund for payment, or on assignments and mortgages. The unfunded debt of Great Britain is of the former kind, and consists partly in a debt which bears, or is supposed to bear, no interest, as debts for extraordinary services, extraordinaries of the army and navy, arrears of subsidies, &c. and partly in a debt which bears interest, resembling a private debt contracted on a promissory note; of which kind are navy and exchequer bills. The bank, by discounting these bills at their current value, and paying the interest due upon them, facilitates their circulation.

Mortgages or assignments are made for a short period of time only, or for perpetuity. In the one case the fund is supposed sufficient to pay both principal and interest within the limited time; in the other it pays a perpetual annuity equivalent to the interest only, government being at liberty at any time to redeem this annuity upon paying the principal: in the former method money is said to be raised by anticipation: in the latter by funding. In Great Britain the annual land and malt taxes are regularly anticipated every year; the bank of England advancing at interest the sums for which those taxes are granted, and receiving payment as their produce comes in. The first loans in the reigns of king William and queen Anne were upon anticipation for a short term. The produce of the taxes destined to this purpose proving insufficient, deficiencies arose, and it became necessary to prolong the term of those taxes. This was done from time to time, and new taxes appointed to make good deficiencies, and to serve as a fund for new loans. In 1711, several duties were made perpetual, as a fund for paying the interest of upwards of nine millions, the capital of the South Sea company, advanced to government; as some other taxes had before been perpetuated to pay the interest of money advanced by the Bank company and the East India company. In 1715, the different taxes which had been mortgaged for paying several annuities were accumulated into one common fund, called the aggregate fund. In 1717, several other taxes were rendered perpetual, and accumulated into another common fund called the general fund. In consequence of these different acts the greater part of the taxes, which had before been anticipated only for a short term of years, were rendered perpetual as a fund for paying not the capital, but the interest only of the money which had been borrowed upon them by different anticipations. Dur-

ing the reign of queen Anne, the market rate of interest sinking from six to five per cent. and this being fixed as the highest lawful interest, the creditors of the public were soon after induced to accept of five per cent. interest; which occasioned a saving of one-sixth of the greater part of the annuities paid out of the three great funds above mentioned. This saving left a considerable surplus in the produce of the taxes accumulated into those funds, and laid the foundation of the Sinking Fund. In 1727, the interest of the greater part of the public debts was farther reduced to four per cent. and in 1753 and 1757 to three and a half, and three per cent. which reductions still farther augmented the sinking fund.

During the reigns of William and Anne large sums were frequently borrowed upon annuities for terms of years, and for lives. On the fifth of January 1775, the remainder of the long annuities not subscribed into other stock, amounted only to £ 136,453 : 12 : 8. Annuities for lives have occasionally been granted as an additional encouragement to subscribers or lenders to government, either upon separate lives, or upon lots of lives, called Tontine, from the first inventor of them.

Sinking funds having generally arisen, not so much from any surplus of taxes as from the reduction of interest, must be insufficient for discharging the debts, even if rightly applied. In a time of peace, after the people have been burdened with many taxes to support the former war, which are perhaps barely sufficient to pay the interests of the debts thus incurred, new taxes would be dangerous, and the easiest expedient, in case of extraordinary expences, is to have recourse to the Sinking Fund. Hence the usual misapplication of this fund.

In Great Britain, from the time that we had first recourse to the ruinous expedient of perpetual funding, the reduction of the public debt in time of peace, has never borne any proportion to its accumulation in time of war. The national debt commenced in 1688. In 1697 it amounted to upwards of twenty-one millions. In less than four years from that time five millions were paid off. In 1714 the debt was fifty-three millions; in 1722, fifty-five millions. From 1723 to 1739 during seventeen years peace, it was only reduced to forty-six millions. During the Spanish and French wars from 1739 to 1748, the debt increased to seventy-eight millions. In 1755, before the breaking out of the last war, the funded debt was seventy-two millions. In 1764, the funded and unfunded debt amounted to 139 millions. In 1775, they amounted to 129 millions. Of the ten millions which have been paid, not five were discharged out of the savings of the ordinary revenue. It appears, therefore, altogether chimerical to expect that the public debt should ever be discharged by any savings from the ordinary revenue as it stands at present.

The annual revenue of Great Britain in time of peace amounts to more than forty millions; a sum sufficient, if unmortgaged, to carry on the most vigorous war. The people therefore are as much incumbered, and their ability to accumulate as much impaired, in time of peace, as they would have been in the most expensive war, had the system of funding never been adopted. This practice has gradually enfeebled every state which has adopted it. This is the case with Genoa and Venice, Spain, France, and the united Provinces.

The raising of the denomination of coin has been an usual expedient for disguising a real public bankruptcy under the pretence of payment

but this is a pitiful and extremely pernicious evasion. A similar expedient is that of adulterating the standard of the coin: the only difference is, that this method of defrauding the creditors of the public is more artful and concealed. An avowed bankruptcy is preferable to such artifices.

The public debt can only be equitably discharged by augmenting the public revenue, or reducing the public expence. The revenue might be increased by a more equal tax upon land, or upon the rent of houses; but most easily and advantageously, by extending the British system of taxation to all the different provinces of the empire, at the same time allowing them a proportional representation in the British parliament. Ireland is certainly as able, and our American and our West Indian plantations, having neither tythes nor poor's rate to pay, more able, to bear a land-tax than Great Britain. Stamp duties might be levied in all countries, without variation, where the forms of law process are nearly the same. The increase of the custom-house laws of Great Britain to Ireland and the plantations, provided it was accompanied with an extension of the freedom of trade, would be advantageous to both. The excise duties might be applied to Ireland without any variation, and to the plantations with modifications suited to their produce and consumption. This extension of taxation, supposing that Ireland and the plantations contain eight millions of inhabitants, would increase the revenue to sixteen millions; deducting one million for supporting the civil establishment of both, out of this revenue, six millions might annually be spared towards the payment of the debt, and as the debt diminishes, a much greater and continually increasing sum, so that the whole might be discharged in a few years.

It is no objection to this plan, that the Canadians have but little gold and silver: for this is the effect of choice, not necessity; their great demand for active and productive stock rendering it convenient for them to have as little dead stock as possible. Their payments might be chiefly made in produce, by means of their mercantile connections.

If it should be found impracticable to draw any considerable augmentation of revenue from any of these resources, nothing remains but a diminution of expence. And the most obvious and effectual means of doing this, would be by relinquishing the colonies which have been the occasion of such heavy burdens. If any of the provinces of the British empire cannot be made to contribute towards the support of the whole empire, it is surely time that Great Britain should free herself from the expence of defending those provinces in time of war, and of supporting any part of their civil or military establishment in time of peace, and endeavour to accommodate her future views and designs to the real distress of her present circumstances.

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